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HAY AND STRAW CONSERVATION

For small-scale farming and pastoral conditions

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HAY AND STRAW CONSERVATION

For small-scale farming and pastoral conditions

by

J.M. Suttie

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FOREWORD

Grazing lands cover a vast area of the earth's surface, and are a source of livelihood to many farmers and pastoralists, but they rarely provide adequate year-round feed, in terms of both quantity and quality, to support highly productive livestock. Since green herbage is only available seasonally in most regions, the provision of feed for deficit seasons has always been a major concern in many livestock production systems.

Hay is the oldest and most important conserved fodder, and it can be made with simple equipment, manually or with mechanization. Many small-scale farmers make hay and store crop residues to carry livestock through periods of shortage. Practices vary in different parts of the world, but follow some basic principles. The residues, straws and stovers of the main field crops, which represent about half of the biomass produced, are used as ruminant feed, although they generally require supplementation. Since these residues are available on-farm, some extra care in their harvest, storage and use is often well worthwhile.

FAO has long emphasized the importance of forage and its position in farming systems, particularly for small-scale producers. This publication discusses hay, hay crops and crop residues in a wide range of situations, as essential components of fodder management in livestock production, and draws on examples from many parts of the world. It addresses technicians, advisers and extension workers dealing with the small-scale farming, traditional sectors and development projects. It covers a wide range of issues, from basic principles to a series of case studies, illustrating the practices and some of the problems of haymaking in developing countries.

The manuscript was prepared by J.M. Suttie, who retired from FAO recently. It uses much information collected in the field during many years with the Organization. It is hoped that this publication will assist the

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improvement of fodder conservation, and thus of livestock husbandry, by small-scale farmers and pastoralists.

Thanks are particularly due to Caterina Batello and Stephen Reynolds of the Grassland and Pasture Crops Group for ensuring that the book was brought to publication.

Marcio Porto

Chief
Crop and Grassland Service (AGPC)
Plant Production and Protection Division

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ACRONYMS USED IN THE TEXT

ADF	acid detergent fibre
ARC	Agricultural Research Council
CP	crude fibre
DM	dry matter
EE	ether extract
GDP	gross domestic product
GNP	gross national product
K	potassium
N	nitrogen
NDF	neutral detergent fibre
NFE	nitrogen-free extractives
P	phosphorus
PGS	pure germinating seed
TDN	total digestible nutrients [obsolescent unit]

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EXECUTIVE SUMMARY

Hay and crop residues are discussed in the context of small-scale farming systems. Haymaking is an ancient and simple agricultural operation. Availability of fresh fodder varies throughout the year, but livestock must eat every day; fodder conservation is therefore desirable in most mixed farming systems. The inedible parts of cereals and pulses - straw, stover and haulm - comprise about half the above-ground biomass of these crops, and much of this can be converted by ruminants into economic products.

Crop residues are very important and widely used as lean-season feed, especially in small-scale production systems, but their harvest, storage and use could be improved. Dry residues are often complementary to hay in feeding systems, and the equipment and techniques used for harvesting and handling are similar, so the subjects have been combined.

While the main aim of haymaking is to store feed for later on-farm use, hay is also a sellable commodity, as it is easy to transport and store. In some countries, urban dairies and draught or riding animals provide a large market, and some small-scale producers make hay for such markets. Others have to sell for ready cash, and feed straw to their own stock. Large arable farms may grow hay as a cash crop, while not keeping livestock themselves.

Techniques and equipment are described at three levels: manual; using animal draught; and mechanized, with the emphasis on the first two. Fully mechanized haymaking is now very sophisticated and developing rapidly, so a detailed discussion is outside the scope of this book.

Hay is made from both natural herbage and sown fodder, either artificial pasture (which may serve for both grazing and conservation) or specialized hay crops. Hay is not a worldwide crop and has, as a part of traditional farming, been localized. Sown hay was a key factor in the intensification of western farming, and has spread to large-scale mixed farming in many parts of the world.

Small-scale production of sown hay is widespread in the drier parts of Asia, especially in semi-arid or irrigated zones, and where grazing is snow covered in winter. Haymaking from natural pasture produces a much poorer product than from sown crops since it is of poor specific composition and from marginal lands of low fertility.

In tropical and subtropical countries, natural hay can often only be made after the rains, by which time the herbage is over-mature and its feeding quality is no better than straw. Tropical grasses mature more rapidly and have a much lower feeding value than those of temperate zones, but such herbage is extensively made into hay where roughage is very scarce, notably in India.

There is a wide range of forage crops suited to haymaking, with species

and ecotypes adapted to all agricultural zones. Hay is not easily made in the humid tropics, and year-round green forage may therefore be used by farmers.

The main hay crops, their cultivation and harvest are described. Selection of crops according to agro-ecological zone, farming system and proposed use is discussed, and other lean-season feeding strategies outlined briefly, since hay is only part of a farm's year-round feeding programme.

Hay and residues should be used in a rational feeding system, and with minimum waste; wherever possible, they should be fed from racks or troughs to avoid spoilage. Coarse hays and residues are more efficiently used if chopped; simple chopping machines are widespread in Punjab and surrounding areas, but rare elsewhere in small-scale farming. The feeding value of straws and stovers can be improved by increased care in harvesting and storage. The palatability and digestibility of crop residues and poor hay can be improved by simple treatment with urea or ammonia, but the feasibility of such treatment has to be decided in the light of local costs and prices.

Thirteen case studies provide a wide overview of current practices and problems with natural and sown hay.

Hay from natural pasture is often of poor quality and from unimproved vegetation, and lack of clear land tenure or long-term rights to cutting and grazing is a major and widespread constraint to improvement. Sown hay is widespread and traditional in semi-arid countries, especially in northern and western Asia, where the crops are almost entirely legumes. Sown grasses are not used by small-scale producers, but coarse cereals - millets, maize and sorghum - are grown and dried as hay, especially in Asia and South America. Small-scale farmers rarely sow for hay in the sub-humid tropics, although it is sometimes done by large mechanized enterprises in such climates.

There is considerable scope for improving small-scale haymaking through better standards of cultivation, use of proven cultivars, better seed supply and higher quality tools and implements.

Crop residues have always been a major feed source in most areas, and in general are becoming increasingly important as forage, as the availability of natural grazing decreases and livestock numbers grow. Harvesting and storage methods could be improved. Straw treatment with urea or ammonia to improve feeding value is now a well understood technique, and its economics should be studied wherever it might be introduced.

Available, improved and adapted technology is often not taken up by farmers, largely because they are unaware of it, even if local research units have the knowledge. Training will be required at all levels to make such information available to the farming public: initially to up-date the skills of advisers and technicians, whose education rarely deals with hay, fodder and hay crops in depth; and then on-farm demonstrations can be undertaken, with extension to farming communities where hay might be economically viable. All training must be in the context of livestock production within the existing farming system.

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CHAPTER I
INTRODUCTION

Hay is the oldest, and still the most important, conserved fodder, despite its dependence on suitable weather at harvest time. It can be made with simple equipment, manually or with mechanization, and many small-scale farming systems make hay to assure livestock feed through the lean season. This publication discusses hay and hay crops in a wide range of situations, emphasizing small-scale techniques. Livestock must have feed all year round. Crop growth is determined by the weather, but green feed is only available at certain times of year, and the shorter the growing season, the more uneven its distribution in time. In all but the most clement climates, therefore, in times of scarcity, if loss of weight and production is to be reduced or avoided, feed must be provided to supplement grazing and green forage. The conservation of forage and crop residues is a traditional way to reduce seasonal variations in availability.

Haymaking involves reducing the moisture content of cut herbage in the field from an initial 70 - 90% to 15 - 20% - simple in theory, but very dependent on the weather and demanding skill and judgement from the farmer. Hay is classed as a roughage, i.e., a feed with over 18% crude fibre and under 20% crude protein in its dry matter (DM); in practice, most hays have a feeding value well below these levels. It is rarely a complete food and must be used as part of an overall feeding system. Crop residues, straws and stovers, mainly but not exclusively from cereals, are also important as lean-season feed for ruminants, and are often used in association with hay. Since the subjects are so closely linked and the technology and equipment similar, they are dealt with together. The emphasis is on crops specifically grown for hay, and on natural grassland. Leys which are both mown and grazed are traditionally used in rotations on large farms in some temperate regions, but for small-scale farmers (and in this context many farms are less than 2 ha arable), grazed pasture is not a practical option.

Storing forage for use in the non-growing season is an ancient practice which probably originated in countries where climatic conditions for hay-making were good, where livestock were important and where herbage could dry off as standing hay. Lucerne, the finest forage and hay crop, was developed in central Asia (Asia Media, when that meant a country!) several centuries before our era.

Storage of straws and crop residues for feed is probably as old as cereal cultivation. The domestication of lucerne was closely associated with the development of the horse as a war animal. The evolution of fodder growing and haymaking, until modern times, was more associated with draught animals, cavalry and transport than with dairying. Until the development of railways and the internal combustion engine, vast quantities of feed were needed, in cities and in the country, to feed draught animals. Such animals have largely vanished from developed countries, but remain important elsewhere, in both rural and urban work.

Natural drying of mown herbage by sun and wind is still the commonest way of conserving fodder, natural grass and crop residues; auxiliary artificial drying is used, occasionally, in some of the more highly mechanized systems. Hay is the small-scale producer's best conserved fodder since, in all but the most humid climates, it can be made with little equipment or costs other than labour. Hay can be made by simple equipment, and, once correctly cured, is easy to transport and store, and can be fed with little or no wastage. Since hay is an appropriate conserved forage for small-scale farmers and pastoralists with limited resources, it should be encouraged where climatic and economic conditions are suitable. Hay is often marketed as a cash crop, usually baled.

Drying, like other methods of conservation, reduces digestibility and intake, related to the time that the herbage is exposed to leaching and other losses in the field. These can be reduced by barn drying and high temperature drying of herbage, and the technology is well developed, but most hay is still field-cured. In the tropics, standing dried natural grass and the roughages derived from field crops are in most cases the cheapest feed for the dry season.

Ensiling, a fermentation process, is now a major conservation method for large-scale enterprises in sub-humid and humid climates, but it is laborious without heavy machinery. Also, it is not marketable, as silage is unsuitable for transport over any but the shortest distance. A separate publication is planned on silage, so it is not covered here.

Modern haymaking technology developed most rapidly in the colder, humid climates of the Northern Hemisphere, where a long winter limits the growing season and snow may for long periods prevent access to standing grass. The industrialization of that zone provided great markets for farm produce and stimulated the consequent commercialization of agriculture. Livestock production in the temperate zones of the Northern Hemisphere has been progressively freed from the seasonality of herbage production by increased use of conserved forage.

The need for conserved feed

Grazing lands cover a vast area of the earth's surface, but they rarely provide adequate (in quantity or quality) year-round feed to support highly productive livestock. This is particularly true of the grasslands of the seasonally-dry tropics, where annual rainfall may be concentrated in a few months or weeks during the hot season (the "monsoon" pattern) and the mature herbage is of extremely low nutritive value. Such grazing lands have a low potential for ruminant development unless supplemented with forage and crop residues from arable land. There is a worldwide lack of statistics on forage area and production; the same is true for "grassland" or pasture. Definitions of pasture vary widely from country to country, and large areas of land classed as forest, wasteland or desert are grazed at some season of the year. Most livestock, however, are kept in mixed systems where the land, not all open grazing, is a mosaic of arable and (usually on land less suited to cultivation) grazing. It is in such mixed systems that hay and crop residues find their main role.

Cultural groups keep livestock for different reasons. Where milk is a major product, haymaking will be much more widespread than where milk is not traditionally consumed and where stock are kept for draught. India, which has the world's largest herd of cattle, is very much a milk-drinking country; fodder and the use of crop residues are widespread; multipurpose stock provide milk, dung, work and hides, but the meat of bovines is not eaten. Multipurpose stock are different things in different countries. In most of central and southern China and Indochina, cattle and buffalo are kept for draught but are not traditionally milked, nor is their meat as prized as that of monogastrics; cattle and buffaloes are usually bred only when replacement draught stock is needed. Such stock can subsist on rough grazing and crop residues, so forage is not important. In contrast, the pastoral areas of China, notably Inner Mongolia, Xinjiang and Xizan, are great consumers of milk and ruminants' meat. The two first-mentioned have a long tradition of forage cultivation and conservation.

Provision of feed for deficit seasons has always been a major component in the improvement of agricultural production. When livestock are adequately fed in the lean season, their output increases, they are fit for draught when most needed and more dung is available for fertility recycling. Before the agricultural revolution in western Europe, for example, livestock were usually in very poor condition at the end of winter, and in some cases had to be helped to pasture when the vegetation began to grow again in spring. Stock not needed for reproduction or draught were slaughtered in autumn and the flesh salted. Winter feed was limited to some crop residues and, perhaps, a little meadow hay. The introduction of crops sown for hay (red clover, ryegrasses, lucerne) was a major step forward in improving winter feeding and crop rotation, with root crops (turnips, swedes, beet) complementing hay in some areas. Improved feed allowed improvement of livestock breeds. Inputs - seed and fertilizer - were of course required, but the net result was a great increase in farm output and saleable surpluses, which permitted the development of a more diversified economy with manufacturing and trading capacity. In the very different semi-arid climate of North Africa and western and central Asia, haymaking, often from lucerne, has long been a very important source of off-season high-quality feed for both the sedentary and pastoral livestock sector.

The area of natural grazing available to small-scale farmers, especially in Africa, is decreasing rapidly as more and more land is put under crops. This has, of course, not been accompanied by a parallel decrease in livestock numbers, since the demand for crops and livestock are related to human population. This has the double effect of seasonal poor livestock feed availability (both quantity and quality), coupled with degradation of the vegetation cover of the grazing lands through overstocking. The danger of damage to vegetation is probably greatest where there is a mosaic of arable and grazing land. The complex question of stocking rates in traditional systems under fully pastoral situations is reviewed by Behnke and Abel (1996). In many parts of Africa, bottom lands, which had provided some dry-season grazing, are now, with increasing population pressure and expanding urban markets, used for vegetables and sugar cane. Intensification of production systems, with careful use of crop residues, is necessary if animal production is to be maintained and expanded to meet human needs for draught and livestock products. This implies more stall-feeding of stock, increased cut-and-carry systems on small farms, and haymaking to cover the dry or cold season periods of scarcity. The example of the irrigated tracts of the Indo-Gangetic plain which have moved, in a century, from extensive grazing of semi-desert and riparian vegetation to intensive irrigated agriculture, with a stall-fed livestock population which exceeds many-fold the original level, may provide examples for other areas.

Figure 1. Making lucerne hay in Altai, Xinjiang; mown herbage piled into cocks to finish drying, so reducing leaf-loss.

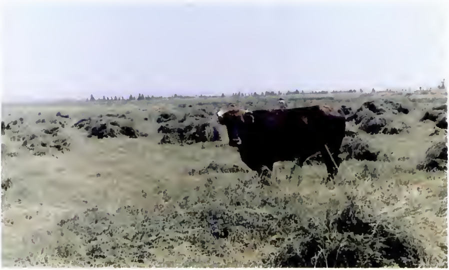
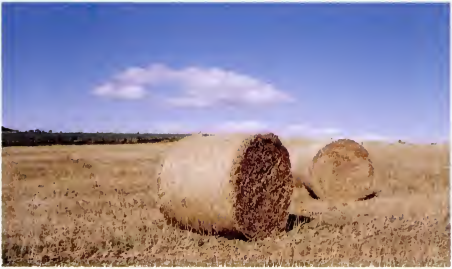


Figure 2. Baled straw, drying in field (Dunecht, Scotland)



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Crop residues - straw, stover, chaff, husks and so on - constitute over half the harvestable biomass of the most widely grown cereals, so the conversion of grassland to arable does not result in a decrease in the availability of dry matter suitable for ruminant feed; but the quality is usually reduced. Therefore high quality forage and hay is needed to complement poor grazing and roughages. The value of residues is increasingly recognized in small-scale farming systems and, in the West African Sahel and savannah zones, where previously they were grazed *in situ*, they are now harvested and stored for on-farm use or sale. These roughages, on their own, are poor feed and require supplementation, but they can be greatly improved by treatment with urea or ammonia.

The possibility of reclaiming "wastelands" (common grazing and forest which have been totally degraded by mismanagement) has been demonstrated on a large scale by the field work of the Indian Grassland and Fodder Research Institute (Jhansi, U.P.), whereby, once some rehabilitation and planting had been carried out, uncontrolled grazing was replaced, through a people's participatory approach, by cut-and-carry systems to supplement and complement crop residues. The technologies and genetic material used have been known for a long time, but now the Institute has developed an integrated, system-oriented package which combines water conservation, re-seeding and sparse tree planting, coupled with a credit facility which allows villagers to stall-feed while the pasture and fodder trees are developing. Similar activities, funded by the Wasteland Commission, are being undertaken at sites in the country's many ecological zones. This work is the basis for training staff from other development institutions who are involved in an ambitious programme of wasteland development.

Hay can be made from natural herbage or sown crops. The main forage sources, in order of importance in the areas and production systems under discussion, are: natural vegetation, crop residues and cultivated fodder. Making hay from selected areas of natural grassland is traditional in many pastoral areas, mainly in the Northern Hemisphere, outside the tropics. Straws, haulms and stovers are very important feeds worldwide. Fodder, although grown in many countries, is usually a minor feed source in the area under discussion, except for the great irrigated tracts of India, Pakistan and Egypt, where it is grown on a vast scale.

"Natural" grassland is difficult to define, but it is that which has not been sown. Little of the world's grassland is natural, insofar as the influence of man through his control of grazing pressure and sometimes of fire, is necessary to maintain the herbage balance and reduce or avoid invasion of woody vegetation. Various stages of conscious improvement are used, other than grazing management, ranging from bush clearing, drainage, fertilizing and introduction of more productive species, to destruction of the native vegetation, followed by reseeding. Great care should be taken before deciding to replace natural vegetation with exotic pasture, especially on marginal land and in areas where the technology is not fully proven.

Hay uses land and inputs in the same way as other crops within the production system, and must therefore compete on economic terms with other crop choices. Economic incentives are as essential for the adoption of haymaking as for any other improved technology. Projects that encourage fodder production "to reduce pressure on the communal pasture," or because of seasonal feed deficits, rarely produce sustainable results. Forage crops require just as much, and sometimes more, agronomic skill and care as other field crops: this is not always recognized by those who have not had to deal with them in the field.

Hay crops come in two great groups: specialized crops used only as stockfeed, and those which are also field crops. Both groups are mainly grasses and legumes. Most specialized fodder and pasture crops are of very recent domestication or semi-domestication, and their seed production and installation techniques often require more skill than that of crops domesticated for thousands of years. Lucerne (*Medicago sativa*), berseem or Egyptian clover (*Trifolium alexandrinum*) and Persian clover (*T. resupinatum)* are of ancient domestication in western Asia, as is red clover (*T. pratense*). Most other sown pasture plants are of comparatively recent domestication. Ryegrasses (*Lolium* spp.) have been grown in western Europe for two or three hundred years but, until the mid-nineteenth century, seed was usually hay-barn sweepings, while white clover (*T. repens*) came into grazed pastures naturally if soil fertility suited it. The Welsh Plant Breeding Station, which pioneered grass and clover selection and breeding, was not founded until 1919! Timothy (*Phleum pratense*) and cocksfoot (*Dactylis glomerata*), although of European origin, were first used as hay crops in Virginia (USA) in the eighteenth century, and re-introduced as crops to Europe; systematic breeding and selection is much more recent. Some tropical grasses have been cultivated sporadically for some time, usually beyond their area of origin, (e.g., *Chloris gayana, Eragrostis curvula, Melinis minutiflora* and *Panicum maximum*), but systematic selection, most collection and breeding dates from the second half of the twentieth century. Cereals, notably oats, maize and sorghum, are very important fodders, for both green feed and conservation.

FAO has always emphasized the importance of forage and pasture in farming systems, as a feed source for livestock and for maintaining soil fertility, re-cycling plant nutrients and protecting the environment. Mixed farming allows a full use of overall farm production of biomass (the straw or stover yield is often of the same order as that of the grain in cereal crops), converting crop wastes, not consumable by humans, into economic products through ruminant livestock. Early major publications from FAO and dealing with the overall grassland and fodder scene include *Improving the World's Grasslands* (FAO, 1951), and for species used as forage throughout the world there were *Legumes in Agriculture* (FAO, 1953) and *Grasses in Agriculture* (2nd edition; FAO, 1965). Later publications include *Tropical Forage Legumes* (1988) and *Tropical Grasses* (FAO, 1989), which deal with tropical forages in detail. The feeding value of fodders and crop residues has been dealt with in *Tropical Feeds* (FAO, 1993), which is also available in electronic form.

This book sets out to deal with hay and residues, considered to be essential components of fodder management for the development of year-round feeding systems. It addresses technicians, advisers and extension workers dealing with the small-scale and traditional sectors, and with development projects. Through a series of case studies, from a wide geographic spread, information on the haymaking practices and strategies of many countries is made available. It aims to assist in deciding where hay fits into production systems, namely where it is a rational choice in year-round-feeding systems and in strategies for dealing with seasonal deficits. Hay often serves to supplement rough grazing and crop residues in small-scale livestock feeding.

The technology and equipment for handling dry crop wastes are the same as those used in haymaking; they are often stored together and used almost interchangeably in feeding. Their harvest, conservation and storage is included as a logical companion to haymaking. A list of botanical names with their authorities and common synonyms is given in an appendix; no attempt has been made to multiply "common" names. It has not been possible to check the specific epithets in the case studies; only obvious spelling errors have been corrected.

The emphasis is on small-scale and traditional, pastoral conditions. Advances in haymaking technology in recent years are many, and these are described briefly, although more applicable to larger-scale farming in tropical and semi-arid zones as well as in temperate regions. The large-scale sector is a specialized and evolving subject, which is constantly absorbing innovations in agricultural engineering technology. There is abundant literature and technical advice is commercially available. Highly mechanized technology is, however, beyond the reach of small-scale farmers.

A loose approach to geographical coverage has been used throughout since, in the context of the subject matter, working definitions cannot be clearly made of "tropical" and "semi-arid." The zoning adopted by the International Grassland Congress at its 1993 meeting has been used as the broad framework for climatic sub-division of the subject. In the humid tropics it is usually easier to maintain a supply of green forage than elsewhere and climatic conditions are rarely ideal for haymaking. The book's emphasis is on those agro-ecological sites and situations encountered in developing countries, the main clientèle of FAO. A series of case studies are presented in Chapter XI to illustrate the practices and some of the problems of haymaking in developing countries. The emphasis is on areas where fodder conservation is traditional.

The principles of haymaking, the equipment and techniques used are described in Chapter II for both natural and cultivated forages. Three, very roughly defined, levels of technology can be discerned:

(i) manual systems with simple tools;

(ii) intermediate systems, with draught animal power or simple mechanization, especially for mowing and transport; and

(iii) fully mechanized systems.

While tropical and semi-arid systems are stressed, techniques for cool temperate areas are discussed briefly, since haymaking is not easy there and much of the modern technology has been developed under such conditions.

Hay crops and their cultivation are described in Chapters III to VI. Most have several uses: they may be field crops (cereals and pulses) or grown for pasture; and are conserved by ensiling where conditions suit. Here, only management for hay is discussed. When hay is made from natural pasture, the hayfields must be managed to provide adequate herbage at the season when hay can be harvested safely. In traditional systems, where common access to grazing is usual, communal consensus and regulation are essential to regulate the seasonal closure to grazing, cutting rights and management of hay lands. The management of natural vegetation for hay is dealt with in Chapter VII.

Fodders are available to suit most agricultural conditions and farming systems. It is important to use those that suit local conditions and systems rather than attempting to adapt conditions to grow a specific forage. The aim must always be high quality hay since, except in cases of overall dry-matter scarcity, it will be used to complement rough grazing and crop residues. The choice of crops is discussed in Chapter VIII. Many tropical hays, especially "bush hay" are no better - and probably of lower - feeding value than straw and stover. When planning haymaking, therefore, the local availability and quality of crop residues should be checked to see if they merit more or less attention than hay. Cereal straw or stover comprises about half the harvestable biomass; this cannot be eaten directly by humans, but can be transformed into economic products by ruminant livestock. Often these are already the basis of ruminant feed. Their rational harvesting, drying and storage is discussed in Chapter IX.

It is reasonable to expect that, once forage has been conserved, care should be taken in its use. The overall ration of the livestock, including minerals, must be balanced for the production expected. The stock should be in good health, internal parasites should be given particular attention, and suitable equipment should be used for transport, handling and feeding. Wastage at the feeding stage is far from uncommon, but can be greatly reduced by the use of suitable troughs, hay racks and, sometimes, by chaffing. This is discussed in Chapter X. The production system determines how the hay is used. Priority will be given to the most profitable or vulnerable stock. Lactating animals, young stock and draught animals are often the main users, but this depends on the farm's production system.

Hay is also a cash-crop, grown specifically for sale. Urban markets can have high demands for hay, green fodder and crop residues for draught stock, dry dairies and recreational stock (race-horses, riding horses, ponies). "Dairy colonies" and in-town dairies and urban family milch stock, which are so common in India and western Asia, have a vast demand for straw, fodder and hay. Pastoralists who require feed for a winter or dry-season gap are an important market in North Africa and western Asia (also for crop residues). Hay can be made where lack of drinking water and fencing would preclude grazing. Like cut-and-carry forage, hay can be produced without the investment in the infrastructure required for grazing.

Hay and straw, although major tools in assuring a year-round feed supply, are, of course, not the only ones. Silage has been mentioned earlier, and is of major importance on mechanized farms. Herd management can often be modified so that stock numbers or feed demand are minimized at difficult seasons. Stock-owners' objectives vary, from the intensive producer, dealing with a fresh milk market, who must maintain production throughout the year, to the pastoralist in marginal conditions whose main desire is to have the maximum number of breeding stock survive the season of difficulty. When planning haymaking as part of the overall farm strategy, alternatives, which range from accepting weight loss to feeding concentrates, should be considered, and are considered in Chapter IX.

CHAPTER II
HAYMAKING

Haymaking turns green, perishable, forage into a product that can be safely stored and easily transported without danger of spoilage, while keeping losses of dry matter and nutrients to a minimum. This involves reducing its moisture content from 70 - 90% to 20 - 25% or less. Techniques for natural pasture, sown pasture and crops specifically cultivated for conservation at three levels of technology are considered: manual haymaking; simple mechanization with draught animal power or small tractors; and fully mechanized systems. It is, of course, possible to have some or all of the operations of haymaking done mechanically under contract, provided that the fields are big enough to warrant it; this is feasible where the climate at harvest time can be relied on. In areas of uncertain climate, however, it is less suitable, since equipment must be on hand for each operation as the weather and condition of the hay dictates. Further notes are given in Chapters III to VI, where hay crops are discussed.

Problems in haymaking vary according to the crop, climate and prevailing weather at harvest:

- Under sub-humid and humid temperate conditions, the main problems are related to slowness of drying, so, to avoid loss by spoilage, the aim is to dry the crop as quickly as conditions will allow.
- Under hot, dry conditions, in contrast, the problems are more likely to be either shattering of the finer parts of the plant, through too rapid drying, or bleaching, with consequent loss of carotene and vitamins.

The main discussion is on climates where drying is a problem, as these are the most difficult for haymaking. Fine-leaf grasses and legumes are traditional hay crops in most areas but, in the subtropics, hay is made from coarse cereals such as maize and sorghum, now mostly in small-scale farming situations, notably in India and Pakistan. On mechanized farms, nowadays, coarse cereals are usually ensiled.

Where hay is made from pasture, rather than arable crops, the fields may be both grazed and mown at different seasons of the year. If the main output of a field is hay, it will still be grazed when the weather is unsuitable, then left for the forage to reach the correct stage at the optimum season for haymaking; the aftermath may thereafter be grazed. With grazing fields, the immediate requirements of the stock has priority but, at the season of peak grass growth, forage availability outstrips the needs of the herd and the whole or part of fields (shut off by electric fences) may be used opportunistically for hay.

TYPES OF HAY

Hay may be made in several forms, according to the conditions, its intended use and the level of technology.

- ***Long hay***, the traditional, age-old form of herbage, mown, turned and carted is the main subject of this book.
- ***Chopped hay*** is an option where conditions for drying are good and systems highly mechanized; it is less bulky and better for mechanical handling, but must be conditioned, windrowed and collected with a forage harvester.
- ***Baled hay.*** Originally baling was by hand (trusses or bottles), and then by stationary machines. It has been automated since the 1950s, with the introduction of the pick-up baler. Big bales which can be individually handled by a tractor-mounted front-end loader are now the main kind in large-scale farming; round bales are the simplest to make and most popular. Their shape sheds rain and resists water better than traditional bales.
- ***Hand-trussed hay*** is widespread in manual haymaking, often as a means of reducing shattering.
- ***Wafered and pelleted hay*** is dense and free-flowing, so it is easy to transport, handle and store. Field units are available, but expensive; they are used for high-quality legume hay in climates which allow rapid drying. Losses are lower than with baling.
- ***"Dried grass,"*** i.e., herbage artificially dried at high temperatures, has been produced from time to time; the process allows conservation of a younger and higher quality material, but it is not currently economically attractive.
- ***Barn-dried hay***. Equipment for fan-assisted drying (with or without additional heat) is now available, but is not widely used.

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PRINCIPLES

The drying process

Moisture-loss is rapid at first, especially from the leaves, as the stomata are open. As the herbage wilts, the stomata close and water has to find ways out through the waxy epidermis of the leaves and stems. The moisture inside the stems takes longer to get out. With the coarser forages, some mechanical conditioning at the time of mowing is necessary if the crop is to dry evenly and in a reasonable time. The rate of drying, of course, depends on the weather: sunshine, wind and the moisture content of the air are the main factors.

Drying should be done as quickly as possible to minimize losses. At mowing, the herbage will contain between 70 and 90% of moisture, and this will have to be reduced to between 12 and 20% before the hay can be stored safely. The safe moisture content will depend on a range of factors, including storage method; local climatic conditions; size of stacks or bales; where the hay is to be stored; and the nature of the crop. As a very rough guide, 25% moisture is recommended as a maximum for long loose hay; 20% for chopped hay and 5% for pelleted, cured hay.

The swath is the mown forage lying in the field; the windrow is either made by raking one or more swaths together or formed directly by a mower-conditioner or windrower. After drying in the swath, further drying in the bale, stack, barn or field may be needed. The harvesting method used should match the rate and total amount of drying that can be expected in a swath or windrow. The quality of hay can be roughly assessed in the field both visually and by handling, twisting a bunch if necessary. It should feel crisp and look bright. Bleached hay always indicates a badly weathered crop.

The drying process in the swath is reviewed by Jones and Harris (1979). The stomata close soon after the herbage is mown. The amount of water to be removed is "roughly equivalent to that transpired by the crop in one day under the conditions of May and June in the south of England." There are two types of limitation to water loss: (i) those which restrict movement of water from plant tissues to the air immediately surrounding the plant within the swath, and (ii) those which restrict the movement of water from the air within the swath to the ambient air. The most favourable conditions for drying are at the swath surface, where both radiation and air circulation are at a maximum. The requirements for drying are a supply of energy and a water vapour gradient decreasing from the evaporating surface to the ambient air; this varies throughout the swath. Within the swath, a microclimate develops which limits water loss. As drying progresses, the humidity gradient within the swath increases because density is reduced as water is lost, so more solar radiation can enter and air-flow is improved. Under British conditions, Jones and Harris (1979) recommend that if the weather is sunny the swath should be spread to get the full benefit of radiation; if conditions are dull but windy, then the swath should be set up for aeration. Again under British conditions, Clark and McDonald (1977) found that in July there was limited evaporation from the swath from dawn to 09:00, high evaporation from 09:00 to noon, a decrease from noon to 18:00 because of decreasing available energy and increasing swath resistance, and evaporation was almost zero after 18:00.

THE MAIN OPERATIONS IN HAYMAKING

Haymaking methods vary depending on crop and circumstances, but the main operations are more or less the same in all cases:

- mowing, which may be combined with conditioning;
- artificial conditioning for rapid drying. (an innovation, and only sometimes carried out);
- turning and tedding to allow even drying of the swath, help dissipate heat and reduce the danger of mould development and fermentation;
- windrowing, i.e., putting the cut herbage into rows for further handling and collection, and sometimes also for protection at night. In hot arid conditions, windrowing protects the crop against shattering and bleaching;
- trussing or putting into cocks (small heaps) are intermediate stages of drying used in some manual systems; and
- carting and storage, with or without baling. In traditional systems the cured long hay is carted and stored in stacks or barns. Baling before storage is much more common in modern, mechanized systems.

LOSSES IN HAYMAKING

To keep losses and spoilage to a minimum, operator skill and experience is essential in giving the attention to detail which is necessary throughout the haymaking process. Much depends on the judgement and experience of the operator. The main way of minimizing loss is to dry the herbage as rapidly and as evenly as possible, and handle it with care thereafter.

Causes of loss include those considered below.

- ***Fermentation,*** with losses beginning as soon as the crop is mown. Enzymatic oxidation of the sap and the activity of bacteria and moulds on the crop surface cause losses, with generation of heat. If the crop is not aerated sufficiently to dissipate the heat, serious damage can occur. Turning and tedding must therefore be prompt and adequate.
- ***Mechanical leaf loss*** occurs during tedding and field handling.
- ***Leaching losses*** occurs if rain falls on the crop during the curing process. Re-wetting of partially dried hay is much more serious than rain on newly-cut herbage, and can cause both leaching and increased mould damage. Should rain be imminent on a partially-dried crop, it should, if possible, be gathered into bigger windrows or cocks.
- ***Further mechanical loss*** occurs during collection, transport and baling. Their severity depends partly on the skill of the operator.
- ***Spoilage in the stack or bale*** is particularly dangerous, and can lead to the loss of the entire harvest, usually as a result of storing material which is at too high a moisture content in over-large units or poorly designed stacks which allow rain penetration or do not allow some ventilation. The ideal moisture content for stacking or baling depends on the crop and the site, and experience and field judgement must be the general guide. The farmer must judge by feel and make a decision in the light of the prevailing weather: when the herbage feels crisp in the hand and does not show moisture when twisted, it is probably at 25 - 30% moisture and ready to bale. Moisture meters are not generally available nor convenient to use in the field, and taking a representative sample is not easy. Fine-leaved, thin-stemmed herbage dries most quickly; large coarse grasses with thick stems and nodes (e.g., Sudan grass) can still have a lot of juice in the stems after the leaves are quite dry. In extreme cases, the fermentation may raise temperatures to levels where spontaneous combustion occurs. Poorly cured or mouldy hay, apart from losses, will lead to poor intake or refusal by stock, and may contain mycotoxins. Mouldy hay gives rise to the human disease known as "farmers' lung."
- ***Wastage during utilization*** includes losses from opened stacks and poor feeding techniques. It is dealt with in Chapter X.

Hay preservatives

Several proprietary preservatives are now available; their purpose is to allow hay to be stored at elevated moisture levels that in the absence of preservative would result in severe deterioration or moulding. Hay of 40 - 50% can be stored. Propionic acid is one of the substances used. Anhydrous ammonia or urea treatment, which was originally developed for improving the digestibility of straw, has given good results in hay by improving its stability under anaerobic conditions, as well as improving its nutritive value. The ammonia, in addition to excluding air, has a fungicidal effect, and also increases the crude protein content of the hay. This is discussed in Chapter IX, where the treatment of straws and stovers is described.

Timing of harvest and stage of growth

Two main factors determine the timing of haymaking: the expected weather of the season and the stage of maturity of the crop. Usually the season will be predetermined by potential availability of herbage and the likelihood of suitable haymaking weather. Pasture, natural or sown, will be managed, by grazing or taking silage cuts as necessary, so that the herbage reaches a suitable stage for curing when good weather is expected. Where sown forage is to be cured, the crop will be chosen and its cultivation organized to match good haymaking weather. If a farm intends to make a lot of hay, consideration must be given to growing a range of species and cultivars to extend the season during which the various crops will be in peak condition for haymaking, and thus make best use of the available equipment and labour.

All steps in haymaking should aim at producing as high a quality of product as possible, but the stage of maturity of the crop is the major factor determining the quality of the final product. Herbage quality drops off rapidly with increasing maturity, especially after flowering, but very young, leafy grass is less easy to handle than more mature herbage, and its yield is less. A compromise between yield and quality has to be made, and, usually, cutting at early to mid-flowering will give a reasonable product. Where tripod drying or barn-drying facilities are available, a younger product can be dried. In "good" haymaking climates, younger material can be cured more successfully than in areas with moist climates, or where there is danger of tropical storms. Cereals for hay are cut at a more mature stage than are pasture grasses, often when the grains are fully formed. Hay from natural pasture is more influenced by the natural growth cycle than are sown crops, and harvesting seasons are often traditional. Many hay meadows rely on natural fertility rather than applied fertilizer, so there is often only one period in the year when they carry sufficient herbage for haymaking.

The time of year depends on the availability of suitable herbage and the weather pattern. The rest of the farming cycle and availability of labour and machinery of course also have a determining role. The aim is always to have both high-quality herbage and a high probability of suitable haymaking weather coincide. Where there is an overall scarcity of forage, farmers may make hay even when the quality of the crop is poor. For example, in the monsoonal tropics and subtropics, a lot of hay is made from very over-mature herbage because the weather during the season when the grass is at its best quality is unsuitable for drying. The product is poor, but even hay which is no better than straw is highly valued. Examples are given in the case studies on Afghanistan, India, Pakistan and the Sahel.

The time of day to start is equally weather dependent, but if the day dawns fair, it is best to mow as early as possible. If the crop is very wet due to previous rain or heavy dew, it may be advantageous to wait an hour or two while the upper part of the crop dries somewhat, since standing grass will dry more quickly than a cut swath. Mowing should not, however, be put off too long, especially under tropical conditions, where afternoon showers are usual. If cut early, the crop can often be turned and windrowed in a morning, before the afternoon rain. Where the scythe is used for mowing, it is everywhere agreed that it is best to start while there is still dew on the herbage, since this greatly facilitates mowing. For haymaking by sickle, however, Skerman and Riveros (FAO, 1989) recommend waiting until the dew has dried. Early mowing allows the other operations, especially turning, to start early and increases the chances of having drying well advanced during the first day.

Deciding whether or not to mow on any given morning may be a problem. In arid areas and climates with a fairly definite dry season (e.g., making oat hay in the North African late spring, or irrigated fodder in arid areas) there is little difficulty. In uncertain climates, however, it is necessary to assess whether there will be a spell of good weather sufficient to allow the making of hay safely, or at least to be able to get it into large windrows. Local weather forecasts, as well as experience, will help, as the time required to cure hay varies greatly with site and climate. In good tropical and subtropical conditions, it can be cut and cured the same day; under humid temperate conditions, several days of good weather are required. In the UK, hay is rarely made in under three days. Delay once the crop has reached a suitable stage of maturity will, of course, reduce the likelihood of producing high-quality hay. Mowing when there is a possibility that poor drying weather will hamper curing may lead to slow drying, long periods in the field, rain damage and possible mouldiness. The final decision is one which requires all the farmer's experience and skill, but in a case of indecision it is probably better to mow than to put off.

The number of cuts per year varies greatly. On natural pasture, only one cut from the spring or summer flush is usually possible (unless the herbage is greatly modified by fertilizer). Sown pasture and fodder may provide several cuts. For pasture, alternate grazing and mowing (for either hay or silage) is often used, according to the needs of the herd and the weather at the time when a surplus to conserve is available. Hay can only be made when forage is available at the right stage and suitable drying weather is available! Irrigated crops in semi-arid areas have good haymaking conditions and cutting should be organized to maximize production while maintaining quality through frequent cuts. This is especially important for the major irrigated forage, lucerne, and details are given in Chapters III to VI. In warm, irrigated areas, cuts may be almost monthly.

HAYMAKING

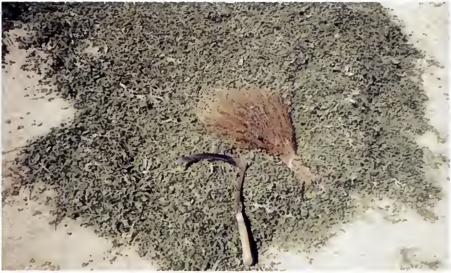
Haymaking requires rapid action to take advantage of such good weather as is available, to make the best use of the equipment, labour and power available, and to synchronize and complete the multiple tasks involved. The amount cut should match the capacity for conditioning, tedding and baling, so that each part of the field is dealt with as it reaches the required moisture content.

General principles

All activities in haymaking must be done on time, from mowing, through turning, to windrowing and baling or stacking, otherwise the crop will spoil. At no point until it is won can mown hay be left. The amount mown daily must therefore correspond to the labour and machinery available for all the other activities that must follow. Mowing should be so organized as to minimize turning and "empty" time for the mower, and to facilitate subsequent operations. Whatever machine is used for tedding or windrowing, it is best to follow the mower round the field in the same direction when the swaths are first moved. If conditioning is done, it should be at, or immediately after, mowing, as should be the first turning to improve aeration and speed up drying.

Under good conditions, the made hay can be carted from the windrow after one or more turnings. The time involved varies greatly according to climate, weather and crop. In dry, warm subtropical conditions, hay can be trussed, baled or carted on the day of its cutting, and indeed may have to be in order to avoid undue leaf-loss through shattering.

Figure 3. Shaftal (*Trifolium resupinatum*) drying on a rammed-earth surface. Note the local sickle; the brush is for recovering shattered leaves (Ghazni, Afghanistan)



PRACTICE AND EQUIPMENT

Agronomic details of crop installation and management are dealt with at length in Chapters III and IV, but it is worth repeating that careful land levelling, at sowing and where necessary between mowings, is essential. Where frosts occur, heavy rolling in spring of fields with stones and pebbles on the surface is very worthwhile for protecting mowers. Heavy applications of nitrogenous fertilizers are limited by increasing density of sward, which hinders drying and can cause lodging, with subsequent harvesting difficulties and losses.

Damage by wheel traffic can lead to severe reductions in stand production and life, either through soil compaction or, especially in lucerne, by damaging crowns and re-growth when field operations are delayed. The lightest equipment compatible with the task should be used; mown herbage should be removed as soon as its condition allows and unnecessary passage on the field avoided. Great longevity of lucerne stands is claimed in some small-scale farming areas (Afghanistan, northern Pakistan) where all operations are manual. Could this in part be due to absence of damage by wheeled implements?

MANUAL HAYMAKING

Mowing

Until the middle of the nineteenth century, all hay was hand mown. There are two basic hand tools: the sickle and the scythe.

Sickles are designed for cutting cereals, but are poorly adapted to mowing hay, and very slow and laborious in comparison to the scythe. They are, nevertheless, widely used, especially in India and Pakistan, often in a blunt, saw-edged version. Where farms are very small and haymaking a secondary task, equipment is kept to a minimum.

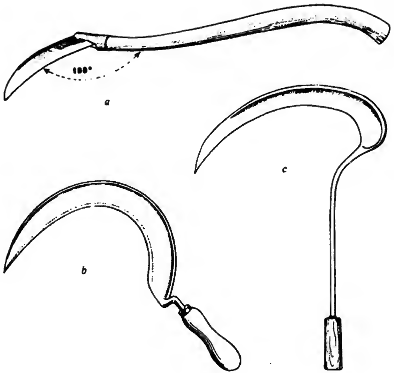
The scythe is the traditional grass-cutting tool of northern Asia and Europe. It can mow at about five times the speed of the sickle. It requires a sward which is reasonably free from obstacles, must be kept very sharp by regular whetting throughout the day, and requires some skill to use. A scythe cuts wheat faster than a sickle, but it does not leave bunches ready to tie. Where the preference in cereal harvesting is for the sickle, small-scale farmers seem loath to acquire additional cutting tools for the minor hay crop.

Table 1. Time taken for haymaking operations in Cameroun

Activity	Per hectare		Per tonne of dry matter		Tractor size
	Time (hours)	**Fuel** (litres)	**Time** (hours)	**Fuel** (litres)	(horse-power)
Hand cutting with machete	12.5	-	3.1	-	-
Scything	6	-	1.5	-	-
Mowing - cutter-bar	2.5 - 4	10 - 20	0.6 - 0.8	2.7 - 4.5	40 - 80
Mowing - disc	2 - 3	12 - 18	0.4 - 0.6	3.0 - 3.6	40 - 80
Mechanical turning	1 - 1.5	6 - 9	0.25 - 0.3	1.5 - 1.8	80
Windrowing - by pitchfork	33	-	8.3	-	-
- by star-wheel	1 - 1.5	6 - 9	0.25 - 0.3	1.5 - 1.8	80
Stacking by hand	25	-	6	-	-
Baling	1.5 - 2	9 - 15	0.4	2.2 - 3	80

Source: Adapted from IEMVT, 1992, who quote Rippenstein, 1977.

Figure 4. Types of sickle



Source: FAO, 1969: 102.

In Africa, the machete (*panga*) is the all-purpose cutting tool and may be used for mowing. Data from Cameroun (Table 1) indicates that the scythe was only twice as fast as the panga for mowing but that may indicate greater familiarity with the local tool. The Argentine Chaco case study also mentions mowing with a machete.

Sickles come in a wide range of forms, and two types of blade edge: serrated or smooth. The blade may be semicircular, straight or slightly curved; it is usually inserted into a wooden handle by a tang; some have the blade attached to a metal shaft with a wooden handle. The section on fodder conservation in

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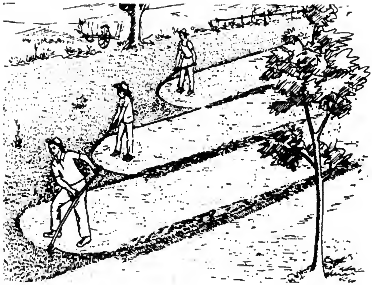
India mentions an unusual yak-horn sickle used in Ladakh. Cutting cereals with a sickle is very slow, but it allows careful reaping and avoids shattering of the ear; this, and its low cost, accounts for its continuing popularity with small-scale farmers. For mowing grass in substantial quantities, the sickle is slow and tiring, so it does not encourage any serious effort to cut forage and make hay in regions where it is the only available harvesting tool. It is a cheap, simple tool and is still very widely used all over the world. Sickle-cut hay is usually handled in bundles from the time of cutting, and is often carried to the homestead for final drying. The individual amounts are usually small, but, in aggregate, a great deal of hay is made this way, especially from irrigated lucerne in western and central Asia and from natural herbage in the monsoon zone. With a tool which is so clumsy, and often blunt, the herbage is usually pulled and cut at ground level; this damages some crops, especially lucerne, and every effort should be made to encourage cutting above the level of the young shoots which provide the next crop. Haymaking is very widespread in Afghanistan and the traditional sickle, used for clover and lucerne, is long-shanked and smooth-edged, often with a long handle. It is kept sharp and wielded one-handed with a scything motion, and works better and faster on lush legumes than would a grain sickle.

The scythe is essentially a grass-mowing implement, worked with two hands. It consists of a blade joined to a handle (the "snath" or "snead") by a ring connector. Two quite different types of blades are used: ground blades (sharpened on a grindstone) and hammered blades (sharpened with a hammer and small anvil). Both are finished off with a whet-stone, which is also used to keep the blade sharp in the field. Ground blades, the older type, are used in northern Europe and North America, whereas the hammered type, developed in Austria, are used in central and southern Europe, and have spread to Latin America. Whetting is the sharpening of the blade, in the field, by special stones (some require water if the herbage is dry) which are stroked over both sides of the blade, starting from the heel.

The blade, of mild steel, has a reinforced back, the end of which forms the tang for connection to the snead. Its length for mowing cereals and herbage is 75 - 100 cm (shorter blades are used for brush-cutting); longer blades require more skill in operation and a stone-free field surface. The width of the blade at the heel is 10 cm or less for mowing, but may be wider for dealing with thick-stemmed material. Sneads are traditionally of wood, although light metal tubes are now also used. The handle of the traditional type is long and has a grip in its middle for the right hand; some have a second grip at the top; an improved type used in Scotland has a Y-shaped snead with two grips.

Figure 5. Mowing by scythe



Source: FAO, 1969: 113.

Sneads vary considerably in design, but are designed to allow the operator to mow with outstretched arms and both hands on more or less the same horizontal plane so that the implement can be swung through a wide semicircle with the blade always parallel to the ground and without undue strain. The length of the snead and the position of the grip(s) should be determined by the height of the user. The blade is attached to the snead by a ring-connector which is fixed by a screw or wedge; this makes it possible to regulate the angle between the blade and the snead. The vertical alignment of the blade can be regulated, by a blacksmith, through modifying the angle of the tang to the blade-back.

Grass, especially thin stands of natural hay, is much easier to mow with a scythe in the morning when the dew is still on it. Scythes are frequently recommended in new areas where hay is being popularized, often with little success; the reason may be that the art of scything, in the western world, is largely forgotten and few technicians now have the necessary expertise to effectively demonstrate this arduous and skilled task, including scythe maintenance. Mowing with a scythe is a skilled job, and very different from cutting with a sickle. Forage crops are mown with wide cuts, advancing in a straight line and cutting away from the standing crop. A scythe cuts about 2.5 times the length of the blade, so a 75 cm one will mow a swath 175 cm wide if the crop is not too heavy, with the width reduced in a denser crop. On good, level, stone-free ground, about 500 m^2 can be mown per hour.

Turning and tedding

Like mowing, windrowing and turning was done by hand until relatively recently Various home- or locally-made wooden forks and rakes were used, and are still common. Turning by hand, without tools, is not uncommon, but very laborious. Metal-tined forks came in latterly. The fork is used for all manipulation of hay during loading and stacking. Herbage may be taken to the homestead for final curing, in a place where it is out of the way of livestock. There are several reasons for homestead drying, including the availability of suitable drying areas, convenience for turning and handling small quantities without having to travel to the field (which may be at some distance in the case of natural herbage in mountainous areas), and also the possibility of theft from the field. Examples of this fairly widespread system are given in the case studies on Afghanistan, Liaoning and Pakistan. Small quantities are often stored on rooftops, in trees and around farm buildings in traditional systems, often to keep it out of the reach of foraging livestock.

Where drying is slow and weather uncertain, the hay can be put into cocks by hand for several days; it may also be cocked when rain is imminent and then re-spread following the rain. Intermediate stacking in large cocks with a central wooden tripod for ventilation was once common in northern Britain for completing field drying before final stacking. Cocks and large windrows are also used in hot, dry areas to avoid shattering and sun bleaching.

Baling started as trussing - hand rolling into bundles - a practice still common in some areas where natural grass is traditionally mown. Small trusses are widely used for legume hay in semi-arid areas of Asia as a means of reducing leaf-loss. In the case studies, trussing is reported from Argentina as well as most countries in semi-arid Asia. Stationary hand presses were developed where hay and straw had to be transported over long distances; they are still used in some areas, as reported in the case study on the Argentine Chaco.

Figure 6. Hand-trussed lucerne drying on bunds (Herat, Afghanistan)

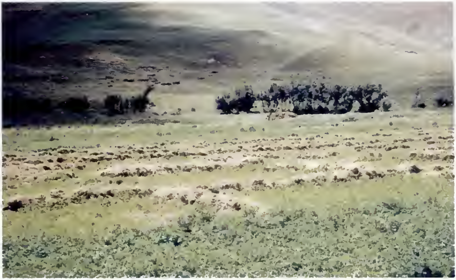
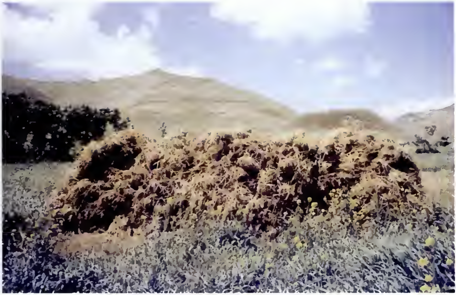


Figure 7. Further drying of lucerne trusses in a loose stack (Herat, Afghanistan)



Transport was the first operation in haymaking to be mechanized - long before mowing - and animal-drawn carts have long been used. In order to better carry the bulky loads, frames are added at haymaking in order to increase the carts' area. Pack-saddles are also used, as well as back-frames and ropes for porters, mainly on land too steep for or inaccessible to wheeled vehicles. When transported by cart, the hay is usually loaded by pitchfork and carefully built on the wagon: the corners should be laid down first, then the sides, and finally the centre, layer by layer, taking care to see that each forkful locks the previous one. Carting high, bulky loads on sloping land is not easy; if the land is at all steep it may be necessary to work with the slope, and this should be taken into account when windrowing the crop.

HAYMAKING USING DRAUGHT ANIMAL POWER

Mowing

Horse-drawn reciprocating-blade mowers were introduced in the early nineteenth century in the USA and soon became the main grass-cutting machine of large-scale agriculture. The mower has a main frame, with a seat for the operator, mounted on two wheels, from which power is transmitted through a live axle and differential gears to the cutting mechanism. The gears of the differential drive run in an oil-bath. The cutting mechanism is connected to the main frame by a double-jointed drag bar which allows adjustment of the cutter bar by levers. A crankshaft and connecting rod (pitman) transform rotary motion into reciprocation. The cutter bar is usually 1.25 m or more long, carrying ledger plates with "fingers" which form half the scissors. The cutting action is completed by the reciprocating knife bar with triangular blades. Knife sections are easily removable by punching out two rivets and inserting new pieces. There is a prolonged swath-board at the end of the bar to lay the mown herbage away from the standing crop.

These mowers are of relatively simple construction and can be maintained and repaired by elementary workshops, but require clean fields and the blades must be sharpened regularly. It is essential that the ledger plates of all fingers be in alignment so that the knife sections slide over them smoothly. The cutter bar is in proper alignment when the crank-pin, the knife head and the outer end of the knife are all in line. Cutter bars and knives are exchangeable. This type of mower has a power requirement of 1.5 kW per metre of cut, and forward speeds of 3 to 8 km/hr are suitable. It is the only type of mower which can be drawn by livestock.

The mower is usually drawn by two animals and enough will be mown at any one time to suit the rest of the handling equipment and labour. The swath should be turned by hand, or star-wheel rake if available, soon after mowing. Further handling will either be manual or by simple equipment. A dump-rake is very useful for forming windrows and gathering the hay for carting. Carting and stacking is as for manual haymaking (see above).

Swath manipulation

Turning and tedding is often by hand, although horse-drawn dump-rakes, sweeps and tedding machines were developed in parallel with mowers, and later adapted to mechanical traction. The dump rake (Figure 9) is the commonest and most useful implement; it consists of a large number of long, slightly curved teeth on a bar parallel to its axle, with a pawl and ratchet mechanism for tripping the rake, worked by a foot pedal by the operator sitting on a seat and guiding the horse. It is used for dragging hay into windrows and for cleaning hay and corn stubble.

Figure 8. Horse-drawn mower (Altai, Xinjiang, China)

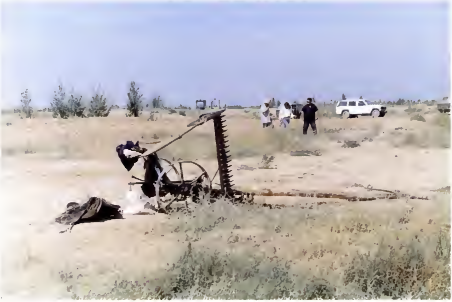
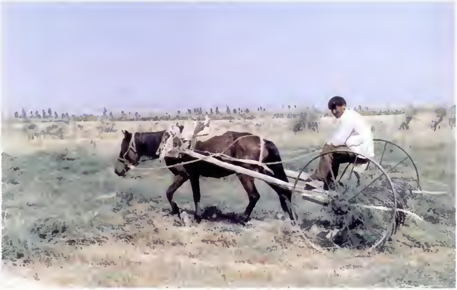


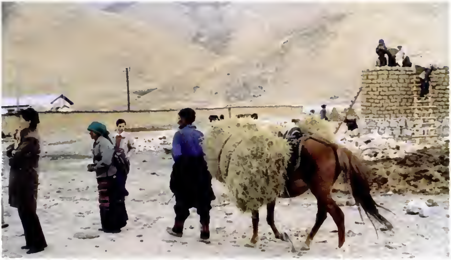
Figure 9. Dump rake, windrowing newly-mown lucerne, (Altai, Xinjiang, China)



Cocks, tripods and rack-drying

Where there is danger of re-wetting, which is very damaging, there is an intermediate stage where the partially-dried herbage is put into small heaps - "cocks" - to dry further with less danger of rain affecting the whole mass. Under sub-optimal conditions, the cocks may be built on wooden tripods to improve ventilation, or the hay may be put on drying racks - all labour-costly operations. They are also useful in hot dry areas where the best quality hay is made by putting it up in cocks, which reduces both shattering and weathering and produces a green, leafy hay high in carotene. Racks and tripods, however, require a cheap supply of poles, not always readily found. Fully mechanized systems attain a similar effect through careful swath handling and windrowing. IEMVT (1992) describe and recommend several drying structures for small-scale farming use. These include a "Canadian tent," which is built from two A-frames with a ridge pole and one or more poles on the sides; tripods; and a "Scandinavian fence" of posts and wire.

Figure 10. Hay being taken to market, above Lhasa, Xizang, China. The climate of the plateau is too harsh for cultivated fodder but some *Pennisetum flaccidum* reaches mowable height in protected places



Collection, loading and transport

Horse-drawn sweeps were developed to push several sections of windrow together for ease of collection, and some have a tumbling action so that they discharge easily. Cranes were also used for loading hay onto wagons or from wagon to stack, and in the field they were especially useful where intermediate on-field stacking was used. Such equipment was used on large farms, and these are now highly mechanized. In small-scale farming systems, loading is by fork and hay is transported on carts, which may be temporarily modified by the addition of frames to increase their base area to allow transport of a greater load of bulky material.

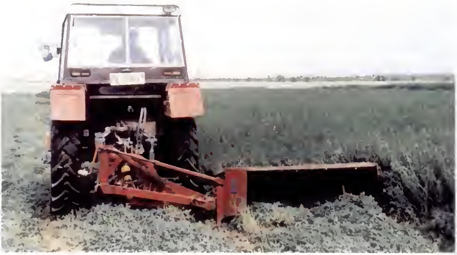
SIMPLE MECHANIZATION

Small tractors are becoming increasingly common in developing countries, and often their owners do some contract work as well as tending their own farms. Old and simple techniques of mowing and sward handling can be introduced with a minimum of equipment and investment, but can speed up and improve haymaking a great deal. A mower, dump rake and some frames to expand the loading area of existing trailers will go a long way toward mechanizing the hay harvest. In the case study on Altai, for example, a centrally-run machine pool with heavy equipment proved less attractive than simple mechanization run by farmer-contractors with the kind of equipment mentioned above.

Mowing

When tractors came into use, reciprocating mowers were adapted to suit them; the first, trailed models worked from the ground wheels, and then mounted models evolved, driven from the tractor's power take-off (PTO). Of the PTO-driven models, mid mounted bars are by far the simplest to work with since the bar and control are in front of the driver and the drawbar is free for other equipment. The close-coupled arrangement allows square cornering. The reciprocating mower's power requirement is about 1.5 kW per metre of cut, and a forward speed of 3 to 8 km/hr gives a rate of 0.2 - 0.6 ha/hr for a 1.5 m cut. Over a season, the work will be about 50% of that "spot" rate.

Figure 11. Rear-mounted disc-mower (Altai, Xinjiang, China)



Swath manipulation

Dump-rakes have been adapted to be drawn by tractors. Finger wheel machines are simple and light implements; they are gear-less. A number of independently mounted large diameter wheels with spring teeth arranged radially are set in an oblique frame. The wheels, which gain their motion from contact with the ground, are free to float and overlap each other. When the wheels are on a single bar, they act as a side-delivery windrower. On double bar machines, the wheels can be arranged in two banks, one before the other for swath turning.

Stationary ram-balers (powered by tractor or engine) were developed for use where hay or straw had to be transported. These have been replaced on larger farms by pick-up balers, but are still used in conjunction with animal drawn and other simple methods of haymaking. The case study on Pakistan mentions that straw is baled for transport to the large cities.

MODERN SYSTEMS

Many levels of equipment and sophistication are now available. With a light tractor, such as those commonly found in small-scale farming areas, and some simple raking or turning equipment, the system will be little different, although quicker, from haymaking by draught animal power. Where fields are large and heavy equipment available, specialized equipment will be used and the hay will usually be baled in the field and stored as bales. The mechanization of haymaking, baling and handling is now highly developed

Mowing

The mower should be able to cut the forage to be handled in a day. A speed of 15 km/hr with a narrow cut of 1.8 m will cut 1.5 to 2 ha/hr. For high output, 2 to 3 m-wide cuts are possible, but the swath should be gathered to 1.6 m to allow passage between tractor wheels and match subsequent equipment; the drying rate is reduced by this thicker row. The mower should be capable of operating continuously, without blockage even in dense and laid crops. Less than 25% of the time should be taken up by turning, travel between fields, delays and adjustments. When there are stones, etc., adjust the mower to cut above them, say 4 cm above the soil. The traditional cutter bar mower was described above. The "finger-less double-knife" mower is less susceptible to blocking, but needs special sharpening equipment. They can work at 10 to 14 km/hr and mow 6 to 10 ha between sharpenings. Self-propelled mower-windrowers, with the cutter bar at the front, are now also available.

Disc mowers

Disc mowers, which have a cutter-bar fitted with two to six rapidly rotating discs, are a more modern tool and stand up much better to situations of poor field levelling and coarse herbage (Figure 11). Their action has a more bruising effect on the herbage than does the reciprocating knife, so the hay dries more quickly. With a power requirement of 7 to 15 kW per metre of cut (this power requirement can double when the machine is worn or cutters blunt) and a forward speed of 10 to 15 km/hr, a tractor of 35 hp (26 kW) is required for a four-disc model. Disc mowers are unsuitable for animal draught. Disc mowers are unlikely to block in laid or heavy crops. Knife maintenance is simple, and a set of knives will last 40 ha under reasonable conditions. Attention must be given to knife height as well as to the fore-and-aft setting of the cutter unit. Disc mowers can operate at up to 16 km/hr, but 10 to 13 km/hr is more practical. Their working rate is 0.5 to 1.5 ha/hr per metre of cut. Double-drum mowers are now widespread in western Europe.

Conditioners

The aim of conditioning is to reduce the period when the crop is at risk; it should not only increase the drying rate but should also encourage even drying. Conditioning is, of course, only really effective when conditions are suited to removing the moisture thus made accessible. Machine conditioning usually leads to some nutrient loss through breakage. Conditioning is most effective when done at cutting or immediately afterwards; it is usually achieved by either crushing or crimping. Crushing is done by passing the crop between plain or fluted rollers; crimping may crush, but also bends the herbage at 5 to 10 cm intervals and may bruise leaves. Modern equipment includes mower-conditioners that partially crush the sward, as well as cutting it, thus accelerating drying. Early mower-conditioners were designed for lucerne in the USA and comprised a mower followed by crushing or crimping rollers. They work well in a medium crop, but not in a heavy one under European conditions. In Europe, drum or disc mowers, 1.5 to 3 m wide, followed by intermeshing rollers, are used but, increasingly, overshot tedders which abrade the herbage against a concave as it passes are commonly used in conjunction with drum mowers.

Swath handling

Tedding immediately after mowing boosts the drying rate. Conditioning or crushing should be done within twenty minutes of mowing. Timing of swath handling is critical and, at a time of peak demand for traction and labour, it is desirable to have a machine with a high work rate and a low power demand. It should have a wide working width and follow the land surface well to ensure that the maximum of the crop is properly treated. Most modern machines use configurations of tines moving in a near-horizontal plane, and some have drums to deliver the crop to one side. If a large windrow is required, the machine can be driven in alternate directions to combine two rows together. Overshot tedders are increasingly used. They have a series of flails on a horizontal axis, which pick up and aerate the swath. Some machines combine several functions and can ted, spread or windrow, depending on the position of the crop-directing cage. Machines for pick-up in line with the tractor, such as balers, must have a swath of uniform cross section.

In cool, temperate conditions the swath has to be raised for aeration. Under hot, dry conditions, it may be beneficial to spread it over the greatest possible area to benefit from the sun. In most temperate situations it is necessary, however, to tease out, mix and turn the swath as drying proceeds. Unless the weather is warm and sunny, the swath should be set up to catch any air movement across the field. Both crimpers and conditioners are designed to set up the swath and assist air movement. If rain falls on a windrow prepared for baling, the windrow should be split into its original parts as quickly as possible, or drying will be very slow. In very hot, arid conditions, too-rapid drying of the leaves leads to shattering and bleaching, but windrowing will palliate this. Drying can be speeded up by collecting the half-dried hay into narrow, compact rows overnight, and spreading it out over all the ground once the soil between the rows has dried in the morning. The swath must always be collected into windrows for carting or baling. Speed of baling depends greatly on the type of windrow presented to the pick-up reel.

Bales and balers

Pick-up baling is now the norm in most mechanized haymaking. Two basic types of bale are made: the standard rectangular bale, which can be handled manually, and the, usually cylindrical, "big bale" of about 500 kg, which is handled using the tractor's front-end loader. A "standard" bale is nominally 36 cm x 46 cm x 90 cm, and weighs 15 to 25 kg, according to the density of the bale and the moisture content of the hay. It is suitable for manhandling and provides a hay ration for four to ten dairy cows. Such bales are useful when small quantities of hay are needed some distance from the store or in buildings not adapted for mechanized handling.

There are two types of standard balers. Most are of the slicing ram type, in which the reciprocating ram that compresses the forage in the bale chamber is fitted with a knife to slice through the herbage at the end of each stroke. If the knife is properly maintained and set, then slices which can be separated will be formed. Bale density can be adjusted from 80 kg/m^3 to 220 kg/m^3 by adjustment of spring-loaded plates. On most balers, the length of the bale can be adjusted over a range of between 1.5 and 2 times the bale width. The swinging ram, or press baler, has a folding action in which the successive charges are not cut. Under similar crop and conditions, it produces a less tidy bale, usually of a lower density than does the slicing-ram baler. Such bales have an advantage, however, in that air can penetrate them more readily and give better ventilation, which is useful in handling a crop with high moisture content.

The pick-up of a baler should be wide enough to deal with a heavy crop; preferably able to take a swath of over 1.5 m width. A combination of narrowly spaced pick-up tines, a freely-floating pick-up wheel and a spring-loaded guide is most likely to pick up cleanly. The flow of the crop from pick-up to bale chamber must be free of obstructions. Easy adjustment of packers is necessary if well-shaped bales are to be produced. If the feed is uneven, the bale will curve away from the denser side and binding strings may become detached.

Knotters should be able to handle a range of twines. Full out-of-season maintenance of the baler, and its knotter, is very necessary.

The machine must be adjusted according to the type and moisture content of the hay, which will vary according to the time of day and position in the field, so continual operator attention is essential. Moist hay gives heavy bales, which may burst the strings if too dense and/or too large. Light, stemmy hay gives light bales with loose strings. Bales should be examined for moisture content and shape as they leave the chamber. In the UK, hay is baled at 20 to 35% moisture, with the higher levels intended for subsequent barn drying. High-moisture-content bales should be made shorter than dry ones. The output of balers varies between 3.5 and 10 t/hr, but is usually around 6 to 7.5 t/hr or 1 ha/hr. Mechanization of loading and handling is by trailing wagon, or systems which, for weather protection in the field, group bales into pyramids of 3 to 15.

The activities involved in handling standard bales are grouping, loading onto transport, unloading, and loading into the store. If carting directly from the baler to the store is possible, then that is ideal, but this is not often the case. Small stacks of bales are often made in the field for a holding period or under temporary cover; the hay is partially protected from the weather while the heat from oxidation and some moisture is dissipated. Field stacking separates the handling into stages in the event of labour scarcity. The shape and size of the heaps should be decided on as an integral part of the handling system, and must not reduce baler output. Stack size is related to field size and topography, as well

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as to building size and layout. It is necessary to estimate how much hay will have to be handled in unit time to avoid spoilage between baling and storage. Single bales can be picked up from rows and loaded directly on to trailers (180 bales per person per hour). Hydraulically operated swinging-arm loaders can tumble-load about 400 bales/hr. A team of three with such methods can haul and store up to 200 bales/hr, or 70 bales per person per hour, which is double the hand-loading rate. Extended chutes and throwers attached to the rear of the bale-chamber allow rapid clearing of the field, but require a lot of trailers. Stacking the bales on a trailer is hard work, and if the labour does not keep up, then baling is delayed. Turning time is greatly increased with such a long train of equipment.

Single bales, as dropped by the baler, are very susceptible to damage from heavy rainfall, and also interfere with the re-growth of the crop if left more than a few days. It is common to collect bales into groups, which are often made into small intermediate stacks in lines or on headlands. If the tops of the stacks are protected - such as by plastic sheeting, tarpaulin (Figure 12) or thatching - they can be kept safely in the field for some time. Plastic covers should be removed periodically to allow condensation to dissipate. Collection after the baler using manned sledges usually slows baler operation. Automated systems, such as random collectors and fully automatic bale collectors, which collect bales and form groups which can be picked up by the loader without further handling, eliminate the need to form them into units by hand. The simplest arrange bales into flat units of eight to ten.

Big bales

There are two main types of large round balers. Fixed-chamber balers have a chamber of a fixed diameter; in the initial stages hay is packed at random, then a rolling action starts when hay comes into contact with the bale-forming mechanism (rollers or chains and slats). This completes the bale with a spiral of compressed, roughly aligned crop. The outer layers of these bales are denser than the core, and bale size is predetermined by the size of the chamber.

In variable-chamber balers, the bale-forming mechanism expands with the bale, which is thus subjected to continuous rolling. Bale size can be determined by tying at almost any stage of the process.

Big balers come in sizes ranging from 0.9 m diameter by 1.2 m length, to 1.8 m diameter and 1.5 m length. Bale density is commonly between 110 and 120 kg/m3.

Figure 12. Standard hay bales covered by a tarpaulin, drying in a humid climate (Alford, Scotland)

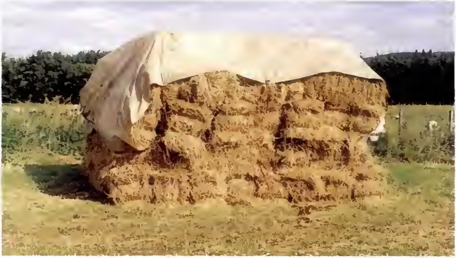
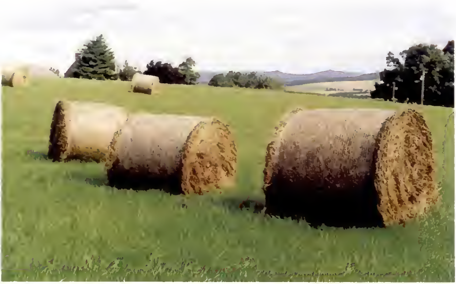


Figure 13. Big hay bales drying as they landed in the field, but spoiling re-growth. (Dunecht, Scotland)



Big balers are relatively simple in operation and construction, but the shape and stability of the bales depends greatly on the shape of the windrow picked up and the skill of the operator. The crop to be baled should be drier than for standard baling, and preferably less than 18% moisture. Bales are wrapped with thin twine and then ejected, and the tying can take 30 - 40% of baling time. Their working rate is 6 - 10 t/hr, depending on the crop and bale size. Bales are left in the field to aerate before they are stored, as artificial drying is not easy. Big bales are greatly used as a means of storing straw, especially for later ammonia treatment. Big bales, which are handled at all times using the front-end loader, should be removed from the field as quickly as possible after baling to avoid damage to the crop, and placed, singly, on their sides in a suitable storage area with a space between adjacent bales. When storing bales, keep in mind the state of the site throughout the year, and not just at the time of harvest.

STORAGE

Hay can be kept for long periods if properly made and correctly stored; in contrast, it can deteriorate rapidly and even be lost by careless storage. The aim in storing hay is to keep it dry and to protect it from wastage due to rots, pests, stray livestock, fire or wind.

Storage areas, whether stack-yards or for bales, should have a dry foundation throughout the year, not only at the season of storage. They should be accessible all year round to the type of transport used, and protected from stray livestock and any fire risk. Where possible, it is better to store close to the point of use rather than in the field. Barn storage is ideal, of course, but is not always feasible.

Stacking

Stacks of loose material are the traditional method of storing large quantities of hay and, apart from barn storage, were the principal system on large as well as small farms until the introduction of the pick-up baler revolutionized commercial haymaking.

Once the hay has been field-dried to a suitable stage, it is carted to the stack-yard and built into stacks. The hay must be carefully built on to carts in the field and taken off in the same order as it was loaded. Under no circumstances should it be tipped off the cart if it has to be hand-forked to the stack, as random hay is very difficult to pull from the heap. Stacking is a skilled job and the quality and safety of the harvest depends heavily on the skill of the builder, especially in regions of moderate to high rainfall. Stacks may be cylindrical or rectangular in section, depending on the quantities involved and the condition of the hay. Often they are built on a base of loose stone for aeration, and in humid-temperate zones a central wooden tripod can be put at the centre of cylindrical stacks for aeration. Skerman and Riveros (FAO, 1989) recommend stacking on a base of hardwood poles, but this will depend on availability and price. When building the stack, the centre must be tightly packed, otherwise the stack will sag as it settles and rain may penetrate. The sides should slope outwards slightly to the eaves and the head thereafter rise gently to a point or ridge. Ropes or nets are used to protect the stacks against wind. Thatching with coarse grass or straw is common in areas where rain is expected during storage. This should not be done immediately, because it is necessary to allow dissipation of heat and moisture following stacking.

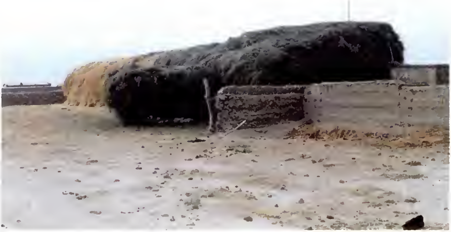
The yard must be kept tidy throughout stacking and storage, and vermin such as rats should be eliminated if possible. Apart from the damage they may do, rodents in stacks in warm areas attract snakes, which can be distracting to the labour when the hay has to be taken out for livestock feeding. Termites are another possible cause of damage. In areas subject to high winds, windbreaks, such as earth walls, have to be constructed, else it is not possible to store hay in the open. In severe cases, the stack may be no higher than the windbreak.

Mud-plastered stacks are traditional in areas where straw is chopped at the time of threshing, and are described in the case studies. This system does not appear to be used for hay. Storage of hay and straw in the forks of trees is widespread, especially for straw, in order to keep it out of reach of wandering livestock.

House-top storage is very common on smallholdings in semi-arid areas where flat-roofed houses are traditional; the house roof is often used as a drying area for other crops, as well as hay. In areas of negligible precipitation, this is an excellent storage method, but where there is rain the hay will be damaged by weathering. One reason for using the roof top is, of course, to keep the hay out of the reach of livestock around the homestead; another reason may be added insulation. This system has an inherent fire risk.

In parts of India and Nepal, *terai* wooden shelters are commonly constructed near the homestead for milch stock, usually buffaloes. *Terai* are flat-roofed and serve as storage platforms for straw and hay, as well as protecting the stock from the sun. Some have a protruding central pole to better retain the stored hay or straw.

Figure 14. Hay stacked behind a windbreak (Altai, Xinjiang, China). In this arid climate, thatching is not needed, but low stacks and protection from high winds are needed.



Fire Risks

Hay is easily set on fire, as are dry crop residues, so care must be taken in siting stack-yards and storage so as to minimize the risks. Stored hay may be accidentally ignited by household fires, by smokers' carelessness, by sparks from bush fires, and so on. Care in siting, cleanliness - including tidying up of loose hay which could carry fire - and avoidance of smoking or other sources of fire near or in the stack-yard will help prevent accidents. Where dry fodder is stored on or close to houses, extra care is needed. Spontaneous combustion can occur when hay is stored at too high a moisture content.

Arson is another risk: an interesting solution to arson of haystacks, in an area where such a means of settling scores is not uncommon, is given in the case study in eastern Turkey, where the authorities insisted on communal stack-yards - if one burnt all would burn!

Bale storage

Advances in mechanization have concentrated more on clearing the field than handling in the store. Elevators move bales from the trailer to the stack, but the speed of operation does not match field handling systems. A team of three is required to feed an elevator and stack the bales, and such a team will handle about 420 to 500 bales per hour. Where the building layout is suitable, front-end loaders are used for stacking in the store.

Fractionation of legume hay

Traditional ways of separating the leaves and stems of leguminous hays for different uses have been noted in China. The final drying of the hay is usually done in the house compounds, and once really dry, it is beaten lightly, the leaves fall and are separated from the stems. The leaves are high-quality feed and are often reserved for monogastric livestock. When the hay is lucerne, the stems will be used for ruminants (see the Liaoning case study (Case Study 5 in Chapter XI)). In very fuel-deficient areas of the Loess Plateau, both sweet clover (*Melilotus* spp.) and North China milk-vetch (*Astragalus adsurgens*) are treated in this way, and the coarse stems used as fuel. This is only done where there is plentiful family labour. A similar technique sometimes is used to collect the leaves of trees and shrubs while still green: the loppings are heaped in a well-ventilated and sunny place and turned, where the leaves fall, are collected and further dried for storage. The remaining branches are used as domestic fuel. *Caragana* spp. are sometimes treated thus on the Loess Plateau, as are *Alhagi* spp. in northern Afghanistan. *Ziziphus* spp. are coppiced and dried in parts of Rajasthan.

CHAPTER III
HAY CROPS - CULTIVATION METHODS

No crop is grown for hay alone; most of those described are used for sown pasture, or are field crops such as cereals or pulses. The cultural techniques and levels of input for other uses may differ from those for haymaking, and therefore that information should be sought elsewhere. Cultivation for hay is discussed, with the emphasis on techniques suited to small- and medium-scale farms. Hay crops are grown on arable land, where they must compete with other field crops on the grounds of profitability. As haymaking costs are proportional not only to the area worked, but also to the weight of the crop, intensive to semi-intensive methods aiming at high yields per unit area are therefore generally advocated.

Where land scarcity is the major limiting factor, increased yield per unit area may be the best way of improving fodder availability. This was demonstrated in Pakistan in an FAO-assisted project (Bhatti and Khan, 1996). Fodder crops cover some 19% of Pakistan's total cropped area, but there is still a chronic forage deficit; the area under fodder remained static during 1977 - 1994, at around 2 600 000 ha, while yields rose over 20%, from 17.4 t/ha to 21.4 t/ha, during the period. Well-grown crops of proven cultivars can produce 60 to 80 t/ha of green fodder (most fodder is irrigated), but there are still problems in assuring the supply of good seed and planting material at farm level.

In another study, in Punjab, Hanjra (1996) gives the results of 200 on-farm trials carried out over three years with the poorest and smallest dairy farmers in central Punjab. The "improved" methods mostly had three parameters which differed from the farmers' own methods: seed quality; sowing method (including land preparation); and date of sowing. The results are presented in Table 2. Yields are below the very high levels attained on research units and some large farms, but the effect of good seed, sown at the correct time, on a well prepared seed bed - all cheap inputs - is striking, with yields improved by 20 to 40%, except for sorghum, where no improved fodder cultivars are available.

Table 2. Yields of fodders with traditional and improved cultivation in the Punjab

Crop	Yield (t/ha; green)		Percentage increase
	Traditional	Improved method	
Sorghum	18.5	20.0	7.5
Hybrid sorghum(1)	-	52.5	-
Maize	15.5	19.4	20.1
Berseem	26.3	38.5	30.9
Lucerne	25.0	34.4	27.3
Oats	15.0	24.6	39.0
Berseem+sarson+oats	32.0	41.3	22.5

Note: (1) Hybrid sorghum is multi-cut.

LAND PREPARATION

Clearing and levelling

Where fodder is cultivated for hay-making, the land must be prepared for mowing as well as put into a fit state for sowing and establishing the crop. Stones, stumps and termite mounds should be removed. Land with a long history of cultivation by the plough may require little or no treatment, but any field to be sown must be cleared of all obstructions to harvesting equipment. Under rainfed conditions, land levelling to facilitate mowing, as well as to make sowing of small seeds at even depth possible, is often necessary: even small humps and hollows make sowing at a uniform, shallow depth impossible and lead to gaps and uneven stands. For irrigated crops, of course, proper levelling is essential for effective water distribution. In-field irrigation structures should be designed to facilitate harvest, especially for perennial and multi-cut crops.

A firm, level seed bed is necessary for all fodders for hay, and for small-seeded pasture-type crops it must also be fine. Preparation methods vary with the type of farm and soil conditions. Whatever the means of primary and secondary cultivations, rolling in the final stages of seed-bed preparation, where possible, is advisable for all small-seeded crops. In tropical and semi-arid areas, work should follow the contour and, where necessary, precautions against washout should be taken. Most fodders have excellent erosion control qualities, once established, but the time of sowing and a short while thereafter are critical.

Fertilizing

Hay is a demanding crop and mineral deficiencies must be made good before sowing. It is a highly extractive crop, since all is removed from the field. Farmyard manure is rarely returned to fodder fields in developing countries, although it may be used on other parts of the farm, especially for horticultural crops. In large areas of the irrigated subtropics where fodder cultivation is important, most of the dung is used as fuel. In mechanized, intensive, large-scale dairying, however, the excreta is now handled in aqueous solution - slurry - which is widely used for top-dressing grass, adding fertility (from concentrates and other bought in feeds) and disposing of a difficult by-product in an ecologically benign way.

Soil fertility status should be determined before pasture installation. Local knowledge may allow a reasonable estimate to be made, but analysis may be necessary. While levels of laboratory accuracy may be very high, the value of analyses are only as good as sampling accuracy, so care should be taken, and advice sought if necessary on sampling methodology.

Phosphorus (symbol: P) is a major nutrient for all crops and its value is well established for fodder and grassland. Soils are usually deficient in available phosphorus unless they have been heavily fertilized in the past. It is essential for root and seedling establishment and should be present in the seedbed in adequate quantity and in a readily available form. It is also very necessary for legume persistence, and phosphatic top-dressings are frequently necessary to support persistence. It is progressively fixed by soil minerals after application, and on some tropical soils this process may be rapid and severe and almost permanent. However, there is thereafter a slow release, on which the sward relies for development. In grazed swards, much of the phosphorus is recycled through droppings. In hay crops, of course, this is not the case.

Potassium (symbol: K) is an essential nutrient, with a relatively high concentration in green leaves. Hays contain 2 - 3% in their DM, so it is a very potassium-extracting crop (a two-ton crop would remove the equivalent of 55 kg of potash fertilizer). It is required to complement nitrogen where high yields are the aim, as in hay production. Soil availability varies widely. Clovers are very sensitive to potassium deficiency.

Sulphur (symbol: S) is required in about the same quantity as phosphorus by plants, and legumes are often very responsive. However, it is much less used consciously as a fertilizer. Soil availability varies very widely. Some of the older fertilizers contained large amounts of sulphur; single superphosphate contains more sulphur than phosphorus; sulphate of ammonia supplies a lot of sulphur; basic slag, which was a major pasture fertilizer in industrial countries, contained appreciable amounts. More concentrated fertilizers with little sulphur are now common (partly to reduce transport and handling costs) and the steel-making process which produced slag is now little used, so the possibility of sulphur supply limiting production must be kept in mind.

Trace elements, or micronutrients, are limiting in some areas and application of tiny quantities in such cases can have spectacular effects. However, they should only be used, including cocktail mixtures, when a deficiency has been identified.

Nitrogen (symbol: N) is, of course, essential to all crop growth and its supply is one of the major limiting factors in forage production. An adequate nitrogen supply is essential, either as fertilizer or through biological fixation by legumes. Leguminous crops with effective nodulation will fix an appreciable amount of atmospheric nitrogen and add it to the overall farm nitrogen balance, but inputs of non-nitrogenous mineral fertilizer are needed to support this, as are increased management inputs in the case of mixed swards. For hay crops, heavy applications of N, including maintenance top-dressings between harvests, are limited by the resultant increasing density of sward, which hinders drying and can cause lodging and subsequent harvesting difficulties and losses. In small-scale farming situations, unbalanced use of fertilizer is a common fault: for unsophisticated users, the eye-catching responses to nitrogen top-dressing tend to eclipse the essential basal inputs of phosphorus and other necessary minerals. Nitrogenous fertilizer on legumes is wasteful and depresses biological nitrogen fixation.

Dressings for establishment will vary greatly according to local conditions, while maintenance fertilizer will depend on the management system. Levels should be decided according to local experience and research. A basal dressing of phosphatic (P) fertilizer is almost always necessary, and potash (K) is frequently needed; for non-legumes some nitrogen is necessary in the seed bed. Sometimes sulphur is deficient and leguminous crops, especially lucerne, can give large responses.

Calcium (symbol: Ca) is necessary for growth and legume nodulation. Under humid temperate conditions, heavy periodic liming, to raise the pH, is sometimes done. This is not suitable for tropical acid soils, but these may benefit from light dressings (600 kg/ha) of lime as a nutrient.

Micronutrient deficiencies should be dealt with where reported.

The forms of fertilizer used will often depend on local availability. For example, single superphosphate is recognized as being the best phosphate source for most fodders and pastures, but its phosphorus content is relatively low (17 to 18% P_2O_5, as opposed to 42% in triple superphosphate), so it is not interesting if long transport is involved.

SEED AND PLANTING MATERIAL

The choice of crops for different situations and conditions is discussed in Chapter VIII. It is always advisable to use clean, healthy seed of the best adapted cultivars available. In developed countries, the pasture and fodder seed market poses few problems, although the availability of seed in bulk tends to be limited to a relatively narrow range of species and cultivars. In many developing countries, the fodder seed situation is difficult, especially for specialized fodder and pasture plants (as opposed to cereals or pulses used as fodders). Often, national priority has, in the past and probably correctly, been placed on producing seed of the major subsistence and cash crops, with fodder taking second place. The importance of livestock in most small-scale farming systems, and the present need for on-farm fodder production, however, mean that this imbalance should be rectified. The international seed market often provides only cultivars suited to a limited range of conditions (whatever the claims of the merchants) and is dominated by countries with a large internal fodder market, notably Australia, New Zealand and the USA.

Traditional fodder landraces, in developing countries, are often only available as farmers' seed from unselected crops, of very doubtful cleanness and purity. It has often been clearly demonstrated that fodder yields per unit area can be greatly increased, often more than doubled, by using good seed of locally proven cultivars and landraces. Many countries have the knowledge and basic seed within their research systems; the problem is how to develop a sustainable, local commercial production and distribution chain. In the sections on individual crops, cultivars will be mentioned; it must, however, be kept in mind that although a cultivar has performed well under similar agro-ecological conditions on another continent or in another country, it does not mean that it can be transferred to a new area with confidence. For example, local disease patterns differ, therefore fodder sorghums selected abroad and imported to Africa, where there is a strong disease challenge, often perform very poorly.

IRRIGATED HAY

Fodder is a widespread irrigated crop in arid and semi-arid zones. Under small-scale farming conditions, usually within a mixed farming system, the greatest areas of cultivated fodder in the developing world are on irrigated lands in the Near East and the Indian subcontinent, often in wheat-rice farming systems and associated with milch buffaloes. Irrigation areas specifically for fodder are rare in the small-scale farming and pastoral sectors, but that in Xinjiang (Altai) (see Case Study 4 in Chapter XI) is a notable exception. In the large-scale sector, however, highly specialized fodder growing, again often associated with dairying, is common. Irrigation layouts should be so designed as to present the minimum hindrance to agricultural and haymaking equipment and should allow easy access for transport of the bulky crop. An adequate drainage system, to allow the fields to be dried off before mowing, is highly desirable.

Components of an irrigation system

Irrigation is not an end in itself, nor does the simple supply of water and seed to land assure a sustainable and economic increase in output. There is a complex interaction between the land and water base, agricultural practices and cropping choices, which interact on the system and affect its production, profitability and labour efficiency. The management and maintenance of irrigation require discipline; traditional systems depend on a stable community decision-making system, and all interventions require, well before proposal or execution, discussion at both household and community level. Irrigated farming communities are well aware of the systems' complexities. The main components are: (i) production activities (choice of crops, cropping and livestock system); (ii) on-farm water management (optimization of yield, and use of labour and inputs); (iii) the delivery system; (iv) the water supply system (relationship with local hydraulic system, reliability, quality, timing of supply); and (v) downstream implications (waterlogging, salinity, disposal of drainage). These are considered in more detail in the following sections.

Production activities

The choice of crops and cropping mixture is determined, within any climatic zone, by water availability, water quality, soils and the local market (both for sale of produce and supply of inputs). Where water is the limiting factor, the producers' aim is often to maximize return per unit of water.

On-farm water management

It is of the utmost importance that best use be made of the water delivered to the farm in order to optimize yield, not only of individual crops, but also of the farm crop mix, to optimize water-use efficiency, and to obviate land degradation due to waterlogging or salinization. The scheduling of water application to suit the plant-soil-water relationship of the site is essential. In addition to a good delivery system, in-field work is necessary. Proper land preparation, including levelling and grading, is essential to facilitate water application, economize on labour and power and to optimize input use (e.g., watering must be so designed that fertilizer remains within the root-run of the crops and is not lost in the drainage water).

These operations are essential to the correct running of an irrigated farm; their application requires knowledge of crop agronomy, land and water management.

The delivery system

The system between the offtake and the farmers' fields requires both management and maintenance. Management must assure equity in water apportionment and assure the timing of each farmer's water delivery. It must also ensure that the canals and works are properly maintained; prior agreement on how this will be done is a prerequisite to any interventions. Maintenance, usually through communal participation, is arduous and can be time-consuming. It is often possible, through some redesigning and modification, to provide systems that are less liable to siltation and therefore require less maintenance.

The supply system

Two main aspects must be studied: the effect of an offtake on water availability for other areas downstream, and possible negative effects on the hydrological system. The final decision on most major offtakes, therefore, cannot be decided by discussion with the potential users alone, as all parties likely to be affected must be consulted. Modern, solid structures not only greatly reduce maintenance labour but allow a modification and prolongation of the cropping system by permitting irrigation over a much longer season.

Downstream implications

Irrigation systems can have undesirable effects on land downstream through salinization, waterlogging and damage caused as a result of drainage water disposal. Both the design of the delivery and the management of the water at farm level are involved. It is very important that these aspects be taken into account before interventions are undertaken. Since the user community may not be directly affected by the downstream damage, such effects must be judged in the light of their wider community and environmental effect.

Types of irrigation

Surface irrigation, in which the water is distributed through flooding by basin, border and furrow, is the ancient, traditional system, which still accounts for the vast majority of the world's irrigated farmland. It is likely that most irrigated small-scale farming fodder will be watered in this way. Surface water is distributed in several ways, and the main ones are discussed briefly below insofar as they affect fodder work.

The subject is very complicated. Standard texts should be consulted (such as Kay, 1986) for information on layout of irrigation units, their organization, and details of irrigation methodology. Crop water requirements and guidelines for their prediction are discussed in another FAO publication by Doorenbos (FAO, 1984). In considering irrigation of hay, however, care should be taken that the method chosen does not unduly hinder the use of whatever machinery is foreseen and that there will be adequate access at haymaking time for the type of transport to be used to remove the crop.

Basin irrigation

Basin irrigation is the oldest and simplest system: a field is divided into one or more basins; each basin is a piece of level land surrounded by a bund which retains water until it has soaked into the soil. It can be adapted to many crops and farming systems, but for fodder production it is very labour demanding and practically precludes any mechanization of harvesting, unless very large basins can be used. The in-field bunds have to be removed at each cutting, and in the case of multi-cut crops, reconstructed thereafter.

Border irrigation

Border irrigation (also known as border-check and border strips) resembles basin irrigation in that the fields are divided into units by bunds, but borders slope away from the farm channel in the direction of water flow. They are not level and the method of irrigating is different. The water is not retained on the field to soak in, but soaks in as it flows over the land, so it is important to use the correct flow for the correct duration to ensure that the correct amount of water infiltrates into the soil. This system is much better suited to haymaking than is basin

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irrigation. If cultivation and/or harvest is mechanized, border width should fit the equipment to be used.

Furrow irrigation

This is the most widely used system for row-crops: water does not flow over the entire soil area, but is confined to furrows between the crop rows, and infiltrates into the bottom and sides of the furrow. It is excellent for large fodder crops such as Napier grass, maize and sorghum, but it is not suited to hay corps. If cultivation and/or harvest is mechanized, row width should suit the equipment to be used.

Spate irrigation

Here the supply is dependent on torrents with only occasional flow, as after heavy rain or snow-melt. Traditional offtakes are very labour intensive, can often only be used when river levels are low, and may be completely destroyed by snow-melt floods in summer at a season when irrigated cropping can be very productive.

Qanat

This is a system (also called *karez*) of tapping underground springs by gently sloping tunnelling to transport it (underground) to cultivated land. It is widespread in parts of Iran and Afghanistan and is used as far east as the Turfan Depression in China.

Piped systems

Various systems of (usually underground) piping of water have been devised to reduce the enormous wastage of open-channel systems and to thus free more land for cultivation. The water is usually supplied to the field through up-pipes with valves (risers) in the case of underground pipes, or through gated pipes where they are on the surface. Accurate levelling and some in-field structures are still required for such systems. Alfalfa risers have their valves just below mean soil level so that once the crop is established the mower and other machinery can pass over them unobstructed.

Sprinkler irrigation

This requires a considerable investment in equipment, but has the advantage that great investment in land-levelling, drainage and other infrastructures is not needed; less land is occupied with irrigation structures; water is more efficiently used; and there is minimal danger of seepage losses and salinization through rising water tables. It does away with the need for in-field structures which hinder fodder harvesting.

Centre pivot

Centre pivot systems are large, computer controlled sprinkler systems which rotate around a central axis. They are widely used for fodder crops in semi-arid or desert areas, such as Saudi Arabia and California. They are primarily for large-scale commercial farms where fodder is a high-value crop, and are well suited to the task.

Cold season watering of hay-fields

Watering of natural hay fields before the thaw is traditional in parts of Russia and Mongolia. Water is diverted from springs and streams on to areas reserved for hay, with or without some in-field structures, and is stored by freezing on the surface. Traditional water-spreading methods practised in the Mongolian mountain-and-steppe zone involve sporadic diversion of streams to develop ice-sheets over hay land which will, thereafter, melt at the onset of the growing season.

CHAPTER IV

ESTABLISHMENT AND CULTIVATION OF SPECIALIZED CROPS FOR HAY

ESTABLISHING PASTURE GRASSES

Perennial pastures are installed for two to five years or more, and shortcomings at establishment cannot be rectified during the life of the crop. It is essential to obtain an even stand across the field, and all operations should be designed to assure this. The small-seeded grasses specially grown as pasture and fodder differ, as crops, from the cereals in that they are mostly of very recent domestication. Indeed some of the tropical species are barely domesticated. Temperate pasture grasses have, at best, been in cultivation for a few hundred years, while most of the tropical species were first grown on a field scale this century. Pasture grass seeds are very small (see Table 3) and their sowing requires care and attention to detail; the few days of establishment are the most crucial for a new pasture.

Some tropical grasses can be vegetatively propagated (usually large or stoloniferous, spreading ones) on a field scale, and this is discussed below. Legume establishment techniques are similar to those for grasses, and their seed treatment and inoculant requirements are discussed below.

When to sow

The establishment period is crucial to the success, longevity and productivity of a sward. Optimum sowing time varies greatly with local conditions and farming systems. Undersown fodders, of course, must be sown immediately after their nurse crop and the date will be dictated by the cropping cycle. In humid, temperate regions, spring and late summer are the two main sowing seasons, avoiding the possible summer drought. Spring sowings should be after the danger of serious frost and chill winds has passed. Under tropical conditions, it is usually beneficial to sow at the very start of the rains to assure as long a growing season as possible and to profit from the flush of nitrogen released by the soil on initial wetting. The shorter the rainy season, the more critical is early sowing. Where the dry season is short, pasture can be sown late in the rains. The peak of the rainy season is best avoided. The usual advice is to sow when rain is expected in the coming days - sound but difficult in practice; light rain is very beneficial but a heavy tropical storm can wash and bury the light seeds seriously.

In areas of continental climate, with severe winters and snow, but with rapid warming in spring, various techniques which take advantage of snow-melt can be used. The seedbed may be prepared and the seed sown just prior to expected snowfall; alternatively, the seedbed may be prepared in autumn, then seed sown on the snow when the spring thaw is expected. The melting snow washes enough earth over the seeds to cover them, provides moisture for establishment and growth. These methods suit the heavier seeds of legumes better than grasses.

In irrigated areas, if there is a rainy season, it may be better to sow on rain and irrigate thereafter, especially where flood irrigation is used. In much of western Asia, the spring is a season of severe winds and sandstorms (*khamasin*, etc.) which can sand-blast or uproot young seedlings. In areas where these winds are known to be prevalent, the season should be avoided and a light seed-rate of a cereal added to provide some protection to the germinating pasture.

Table 3. Seed weights of some grass species

Crop	**Seeds per kilogram**
Cereals and tropical grasses	
Avena sativa - oat	30 000
Zea mays - maize	very variable
Sorghum bicolor (syn. *vulgare*) - grain sorghum	25 000 - 70 000
Sorghum drummondii (syn. *sudanense*) - Sudan grass	100 000
Temperate grasses	
Bromus catharticus (syn. *unioloides*) - rescue grass	135 000
Dactylis glomerata - cocksfoot	725 000 - 1 250 000
Lolium multiflorum - perennial ryegrass	440 000 - 550 000 440
Lolium perenne - Italian ryegrass	000 - 585 000
Phleum pratense - timothy	2 000 000 - 2 600 000
Tropical grasses	
Cenchrus ciliaris - buffelgrass	350 000 - 450 000
Chloris gayana - Rhodes grass	3 300 000 - 4 400 000
Eragrostis curvula - weeping lovegrass	3 300 000
Eragrostis tef - teff	2 500 000 - 3 000 000

Seedbed preparation - rainfed crops

A seedbed of medium tilth, as for wheat, should be aimed at under humid-temperate conditions. Where the intensity of rainfall is relatively low, finer seedbeds can be used. Too fine a tilth may lead to excessive wash, and too rough a tilth will make control of planting depth difficult and may lead to seeds and seedlings being buried. Ploughing should be done well in advance of sowing where possible, and the seedbed prepared by discing and or harrowing immediately before sowing. Rolling with a Cambridge roller, when available, is a great help in firming the seedbed. It helps push any small stones, which might hinder mowing, into the soil. The cleaner the seedbed, the greater the chances of a quick and vigorous establishment. On newly cleared land, weeds are not usually a serious problem at the establishment stage. In the majority of cases, however, hay crops will be sown on old arable land, which is certain to have a heavy weed burden. Every effort should be made to reduce this during previous cropping, but it is still likely that the hay seedlings will have to compete with many weeds. This is especially serious for tropical hay species, which have very small seeds and are often tiny, even in comparison with temperate hays, at emergence. Direct seeding of grass into stubbles that have been cleaned by herbicides is possible where agriculture is sufficiently mechanized.

Sowing

All pasture seed is small and those of the grasses are light. Seed rates are low, but the seed expensive; care in adjustment and use of sowing equipment is very necessary. The seed of temperate grasses and most legumes is free-flowing and does not present problems in passing through seed drills. Tropical grass "seed," however, is not generally free-flowing and usually consists of a large amount of inert material (empty spikelets, immature seed, but not trash or weeds) with a relatively low seed content of medium germination; for this reason it is necessary to know the pure germinating seed (PGS) or pure live seed percentage before deciding how much to sow. Cleaning the seed to a higher degree of purity is not an option, since such small differences in specific gravity are involved that wastage of seed would be high. In addition, the seed is so small that, if pure, the seed-rates would be so low as to make sowing even more difficult. Some tropical grass seed has a period of dormancy immediately after harvest, which may persist for months - *Cenchrus ciliaris* and *Chloris gayana* are among those involved. At medium altitudes in Kenya, the germination of *C. gayana* seed in a store at ambient temperature reached a peak at about 30 months after harvest. Seed of temperate species from reputable companies is generally of high standard and germination and purity rates are high; farm-harvested or locally-acquired seed should be tested before use. Seed rates are given under the crops. Pasture seed is expensive and, in many developing countries, difficult to obtain. Just enough to ensure a good stand should be sown; increasing the seed rate in no way compensates for poor seed-bed preparation or inadequate fertilizer at establishment, and is very costly!

Drilling

For hay, seed should be either sown in close drills or broadcast. Whatever the method used, great care must be taken in ensuring shallow sowing and even seed spread. Seed rates for pasture are far lower than those for cereals. Broadcasting the seed presupposes broadcasting the fertilizer, and that may have a marked effect in encouraging the growth of weeds during the initial stages of establishment. A cereal drill with a fluted or studded roller feed can be used for all temperate grasses and legumes, and, for some models, special auxiliary small-seed boxes with a brush feed are available, which usually broadcast the seed behind the coulters. Close-row drills are preferred. A drill has the advantage that fertilizer can be applied at the same time as the seed. Drills are perfectly satisfactory for temperate species which can be sown at depths of 1 to 3 cm. When sowing tropical species, the coulters should be raised until they hardly touch the ground, and the down-tubes pulled out to avoid the seed being too deeply covered; the merest covering is sufficient. Many tropical grasses, including buffelgrass and Rhodes grass, have awns or bristles and do not run freely, so care must be taken to avoid bridging in the hopper. The seed may be mixed with a ballast or fertilizer, but great care must be taken to avoid its separating out in the box. If seed is mixed and sown with the fertilizer, this must be done, in the field, drill-full by drill-full, to minimize separation of the two components.

The simple, animal-drawn drills and modifications to ploughs successfully used for cereals and some leguminous fodders in Asia are not suited to tropical grass seed, but could probably be used for ryegrass. Specialized grass-sowing equipment, of course, can make establishment surer, but it is expensive and difficult to justify unless large areas are involved; the Brillon seeder, which sows between two small cultipacker rollers, is a very effective tool on good, level seedbeds, but is expensive, heavy and difficult to transport.

Broadcasting

Broadcasting can be done by seed-barrow: a long, light seed box with two shafts and a single wheel, pushed by one man. There is a more modern version, tractor mounted on the hydraulic lift and PTO driven. In trials, two men taking turns on a hand barrow could easily sow 4 ha/day, and the brush-feed was quite adequate to deal with the hairiest tropical seeds. This simple and effective implement is now difficult to obtain. Hand-driven centrifugal seeders (excellent for many legumes) are not suitable for tropical grasses, and mixing seed with fertilizer and then putting it through a fertilizer spinner is totally unsatisfactory. For hand broadcasting, the seed should be mixed with a ballast of a similar specific gravity and weighed out into lots for specified areas; the field is then marked by temporary pegs so that each area is covered by one seed lot. Marking out the land and weighing the seed into lots is especially important when the labour is not experienced. Seed is very expensive, so the extra care is usually well recompensed by reducing the common mistake of too dense sowing in the first part of the field and no seed left for the last.

Early management

Despite the care taken during land preparation to reduce the weed challenge, a considerable variety of weeds will probably be present in quantity as the crop emerges. If their number is not so great as to risk shading out the crop, it is probably best to wait until the forage is high enough for a light grazing by cattle. In pure stands of grass, selective herbicides can be used to remove broad-leaved weeds; the situation is more complicated in mixtures and leguminous crops. Mowing is an alternative to grazing, but care must be taken to avoid leaving a lot of dead material on the young sward. A first cut with a forage harvester can be used to remove the cut material and use it for feed or silage.

The main aim in the first year of establishment of a perennial species is to build up a strong sward which will retain a high yield potential over the span of years foreseen, and all activities should be geared to this. As soon as the first weed control interventions have been completed, grass fields should receive a top dressing of nitrogenous fertilizer to speed up growth and develop strong individual plants. Whether early defoliations are by mowing or grazing will depend on the crop, the season, the weather and the needs of the farm production system. Both overgrazing of the young sward and poaching by heavy stocking when the land is wet should be avoided. The height of the sward at first cut or grazing will depend on the grass in question: temperate grasses should be grazed once they are about 10 cm high, and taken down to 3 to 5 cm. The individual plants of tropical grasses are mostly much larger, and grazing should begin at 25 - 30 cm high and stop at 8 - 10 cm. Short grazing periods, with the stock removed thereafter, are always necessary. Young cattle are best for grazing pastures at the establishment stage; mature stock are heavier and cause more trampling damage; sheep are more selective feeders.

Grass establishment under irrigation

The techniques are similar to those for rainfed land, but on most soils it is desirable to irrigate before final seedbed preparation, wait until the soil is workable, sow and have the seed germinate on residual moisture, and allow only a very light first irrigation. Irrigation after sowing and before emergence of the seedlings can lead to "capping" and poor stands. In areas of cold winters, it is possible to fill the profile with water immediately before the frosts and have a moist seedbed at the spring thaw. All cultivations must ensure that the land is left level and free from hollows which would allow even slight ponding with subsequent gaps or disease-prone spots (through waterlogging) for the crop. The crop is drilled (or broadcast) in the usual way and then the in-field bunds and irrigation structures are raised. Where there is adequate rainfall for establishing the seedlings, it may be preferable to rely on the rainfall for the initial stage, and irrigate thereafter.

Undersowing and nurse crops

Pasture crops are frequently sown together with cereals (nurse or cover crops). The grain is harvested and the sward develops thereafter. This saves a season and cuts out the tillage for one crop. The cereal is sown in the usual way and then the pasture seeds are immediately broadcast or cross-drilled more shallowly. The cereal at the early stages provides some shelter to the pasture seedlings but, thereafter, they suffer seriously from shading and competition for light, water and nutrients. Sowing without a cover crop usually leads to a far better establishment of the pasture. The better the cereal crop, the greater the risk of damage to the undersown grass, and if the cereal lodges, large areas of the pasture will be lost. Undersowing, which originated when cereal growing methods were less intensive and crops consequently lighter, is, nevertheless, still popular. Where legumes or grass-legume mixtures are concerned, undersowing is even less commendable.

Instead of sowing pasture in a cereal crop, it is often possible to sow the pasture seed with a light seed rate of an arable silage or grazing crop, such as oats or barley, which is harvested early in the season and gives the young sward a good chance to develop. Teff is used in this way in South Africa for establishing *Eragrostis curvula.*

Undersowing can be a useful technique where strong winds and sandstorms are a problem at establishment time. Grass can be undersown in row-crops; in eastern Africa, Rhodes grass and molasses grass (*Melinis minutiflora*) are regularly established under maize. The seed is broadcast under the maize (usually by hand) after the last weeding. The stover must be removed immediately the crop is harvested, and a slashing to remove tall weeds is desirable. The crop is not grazed until after the onset of the next rains.

Vegetative propagation of grasses

Some tropical grasses are, on occasions, propagated vegetatively, usually stoloniferous or rhizomatous species, or large, tufted or tussocky ones. It is done where seed is difficult to produce or where clonal material is used (e.g., some cultivars of Bermuda grass (*Cynodon dactylon*), pangolagrass (*Digitaria decumbens*), or elephant or Napier grass (*Pennisetum purpureum*). Land preparation is similar to that for sowing, but the final tilth need not be so fine. Stoloniferous or rhizomatous grasses are planted by pieces of stolon or rhizome, either hand-set at wide spacings (they soon cover the ground) or broadcast and buried by harrowing or discing into moist soil. Large tufted grasses are row planted, by splits. Clumps are dug up and the splits prepared by cutting off tops and long roots (which would in any case die) and dividing the clump into units of two or three tillers. Great care should be taken not to dry out the planting material and this work should not be done in full sunlight. Splits can be planted directly into moist soil (do not open planting holes beforehand, but only immediately at planting) but are better piled up loosely in the shade, watered and covered with sacking for a few days until new roots begin to appear. Elephant grass is planted by stem cuttings in the same way as sugar cane.

LEGUME ESTABLISHMENT AND SEED TREATMENT

Legumes are grown for their high quality fodder and as a soil-improving crop in rotations. Many are melliferous: white and red clover and lucerne are noted honey producers. Where large areas are to be grown, the possibility of harvesting honey should be considered. When seed is to be produced, bees are useful for pollination. Land preparation, seedbed preparation, and sowing are the same as described for grasses.

Legume seed treatment

Legume seed often requires treatment before sowing to improve the speed of germination and to assure proper infection with the appropriate root-nodule bacteria. Pasture legumes usually have a high proportion of seeds with impermeable seed coats which do not imbibe water and which, therefore, do not germinate when

Table 4. Seed weights of some legumes

Crop	Seeds per kilogram
Fodder legumes	
Hedysarum coronarium - sulla	230 000
Lotus corniculatus	825 000 - 925 000
Medicago sativa - lucerne	480 000
Medicago falcata - yellow lucerne	510 000
Melilotus alba - sweet clover	550 000 - 600 000
Onobrychis sativa - sainfoin	55 000 - 66 000
Trifolium alexandrinum - Egyptian clover; berseem	440 000
Trifolium pratense - red clover	440 000 - 660 000
Trifolium repens - white clover	1 650 000
Trifolium resupinatum - Persian clover	1 480 000
Vicia sativa - vetch	18 000
Pulses	
Cyamopsis tetragonaloba - guar	45 000
Pisum sativum - field pea	very variable
Glycine max - soybean	very variable
Vigna unguiculata - cowpea	8 000 - 10 000

sown but can lie dormant in the soil until such time as the seed coats loses its water-resistance; such seeds are said to be "hard." This is an excellent character for survival in areas of unreliable rainfall, but is not desirable when rapid establishment of a fodder crop is wanted at reasonable seed-rates; such seeds require scarification.

Legumes only thrive and fix nitrogen when in symbiosis with their specific root-nodule bacteria of the genus *Rhizobium.* When dealing with a crop new to an area, or sowing on newly cleared land, or using fields which have not had the legume in question for some time, it is often necessary to inoculate the seed with a culture of their specific bacterium.

Identification of effective nodules in the field

Growing crops should be examined (during active growth) to establish the state of their nodulation when deciding whether or not to inoculate sowings under similar conditions. Newly-sown legumes should always be examined for nodulation, to check on the effectiveness of the inoculation process and gather information for further sowings. Effective nodulation usually takes place within a month of planting.

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Seedlings should be dug up carefully (not pulled) and their roots examined. The presence of large nodules on the tap-root and the main laterals in the top two to three centimetres of soil and which show a pink coloration on cross section (due to the presence of haemoglobin) indicates successful nodulation.

Seed scarification

The purpose of scarification is to allow the entry of water into the seed through either an impermeable testa or (as in some *Stylosanthes* spp.) pod, thus speeding up germination. Hard-seededness is only partially a characteristic of species or cultivar and can be greatly affected by weather during seed maturation. Mechanically harvested or threshed seed is often sufficiently scarified by abrasion by the machinery. Hand-harvested and -threshed seed of tropical legumes, however, often shows much more hardness than machine-threshed seed. Three scarification methods are commonly used: mechanical, hot water and acid. Only mechanical scarification should be used in extension work unless a highly-qualified technician is present throughout the whole scarification and sowing process. The qualities of the three methods are summarized below:

Mechanical scarification can be done in small to industrial quantities, and consists of either abrasion or concussion of the seed. At a laboratory scale, a box with a removable bottom (sized to take a sheet of glass- or sand-paper) is used. The seed is spread on the abrasive paper and rubbed with a rubber pad. Medium-sized samples can be dealt with by rubbing the seed on a smooth concrete floor with rubber-soled shoes. Large samples can be scarified in rice-hullers, in concrete mixers with some sand, and in custom-built machines. Mechanical scarification is cheap and simple, treated seed can be stored for weeks, the seed can be inoculated after treatment, and the treatment does not initiate germination. Errors are unlikely unless the seed is over-enthusiastically treated, and ground to meal!

Hot water scarification can be done in small to medium quantities. The seed is immersed in hot water (often boiling) and kept for a specific time, varying according to species. The system is simple, but requires very close supervision. It has many disadvantages. Cold-water soaking is used on *Trifolium alexandrinum* and *T. resupinatum* seeds when they are to be sown into shallowly flooded fields, but there one objective of the soaking is to prevent the seed from floating. Hot-water scarification is open to operator error (cooked seed); the process initiates germination so the seed cannot be stored for even short periods, and if sown and no rain falls, there will be a lot of mortality. If sowing is not possible (e.g., heavy rain falls during the scarifying period) the seed will ferment unless constantly aerated; inoculation is difficult; some species exude a sticky mucilage on wetting and the seeds cohere (e.g., *Neonotonia* spp.).

Acid scarification consists of immersing the seed in concentrated acid, usually sulphuric, for a specified time. This technique is suitable for seed testing purposes and for very small quantities. It is not for use in the field!

Seed Inoculation

The purpose of inoculation is to coat the legume seed with a sufficiently high number of live rhizobia of the correct strain to provide rapid and effective nodulation in the field. Various types of inoculant are produced, but peat-based powders are recommended for field use. Great care should be taken to ensure that the inoculant is, at all times, protected from high temperatures, direct sunlight and bactericidal materials. Seed inoculation is simple, but prone to careless errors. The inoculant powder should be mixed with an aqueous solution of a sticker, 15% gum arabic is suitable and this gum is widely available in the markets of many tropical and subtropical countries. The peat powder is mixed into the sticker immediately before use; the seed is heaped on a clean concrete floor or similar surface, and the inoculant poured on and mixed thoroughly with a shovel or in a cement mixer or similar machine, **but** avoid mixers that have been used for seed-dressing. The quantity of liquid is determined by practice, and the aim is to cover the seed without excess of moisture. The treated seeds should immediately be spread to dry, in the shade, in a thin layer and, once dry, sown as soon as possible.

Pelleting to protect the inoculum on the seed

When seed is to be mixed with acid fertilizer, such as single superphosphate, at sowing or where there is a danger of the seed being exposed to drought and sunlight after sowing, a process of pelleting can be used to protect the inoculum. It usually involves coating the inoculated seed with either lime or rock phosphate using a sticker such as a 45% weight/volume gum arabic solution. Properly pelleted seed may be stored at room temperature for up to a month. To obtain survival in pellets, only peat-based inoculant should be used.

A common method involves using a most widely available sticker, namely commercial gum arabic, which is used as a 40% - 45% weight/volume solution. As it is slow to dissolve, it may require warming. It is best to prepare the gum arabic the day before and leave overnight. It is essential that the gum be free from preservatives. Gum arabic is in itself a nutrient, and no other nutritives (e.g., sugar) are used. The coating material must be very fine (100% to pass a

#300 mesh sieve). Agricultural lime is too coarse; plasterer's whiting and very fine lime (calcium carbonate) are suitable for clovers and temperate legumes. A quantity equal to about 25% of the seed weight is needed for seeds the size of white clover; the smaller the seed, the more material required for pelleting. There are two types of *Rhizobium* to be considered: the type associated with clovers and most temperate legumes is a fast-growing acid-producer for which lime is used; the other type, associated with most tropical legumes, is a slow-growing alkali producer, for which rock phosphate should be used. Table 5 provides a guide to the quantities required, but these will have to be modified to suit local conditions.

Table 5. Seed sizes and coating quantities

Seed size	**Seed**	**Light pellets**		**Heavy Pellets**	
	(kg)	Adhesive (ml)	Coating (kg)	Adhesive (l)	Coating (kg)
Small	6.8	284	3.4	1.14	6.8
Small to medium	10.2	284	3.4	1.14	9.0
Medium	13.6	284	3.4	1.14	9.0
Large	27.2	284	3.4	1.14	6.8

Source: Adapted from *Tropical Forage Legumes* (FAO, 1988).

The inoculant powder is thoroughly mixed with the sticker immediately before use, and the adhesive is applied to the seed, sufficient to make it thoroughly sticky without becoming too wet. The coating is then applied all at once and the heap turned, or tumbled, until the pellets are formed. The seed may be sown immediately, but it is best if allowed to dry for a few hours in the shade to harden. Large pellets must be allowed to harden or their coating may fall off.

CHAPTER V

HAY CROPS - CEREALS AND GRASSES

CEREALS AS HAY CROPS

Cereals are the main source of human food and are, as a group, the most widespread crops. Most are also grown as fodders, or used as fodder when market conditions make that interesting. Their straws and stovers are very important sources of livestock feed, especially for large ruminants, and cereal stubble is often grazed. Straws are far more appreciated in developing countries than in more intensive systems. Whereas straw, which has lost most of its leaves, is a coarse, poor feed, excellent hay can be made from cereals if they are cut while they are still leafy, otherwise the product will be little better than straw. Oats and barley are commonly grown for hay, while wheat is not as good, and rye is coarse. Drought-affected crops are frequently made into hay.

SMALL-GRAIN CEREALS

These are the staple crops of the temperate zone, as well as much of the subtropics, where they are grown in winter, or at altitude. Wheat is the major cereal; barley, which is important for malting as well as for human and livestock food, is next in importance; oats and rye are of local importance for grain, mostly in cool areas of low soil fertility. Oat is also widely grown specifically as fodder and stock-feed.

The cultural techniques for cereals are well known and widespread in field-crop growing. "White-straw crops" are drilled with a cereal drill or broadcast into a well-prepared, clean seedbed at high seed rates. Seed-bed fertilizer should be according to local recommendations, and many drills can place some of the fertilizer at the same time as the seed. Top-dressing with nitrogen should be foreseen; in the case of multi-cut fodders, further top-dressing should be provided after each cut but the last. Little weeding is done, although the usual herbicides can be used and tall weeds removed by hand. In Asia, cereals are frequently hand-weeded and the weeds carried off as green fodder. High yields of seed can be expected from fodder cereals. Seed of specialized fodder oats are not, however, always freely available in developing countries.

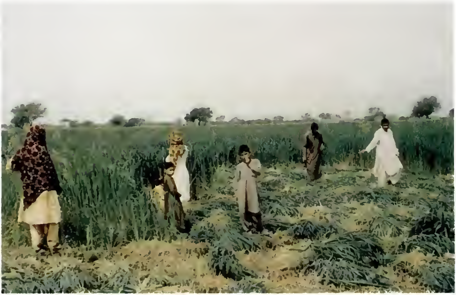
Oats

Avena sativa, A. byzantina, and *A. strigosa*

A tall, annual cereal, widely grown as a fodder in temperate and subtropical countries. It also does well in the high-altitude tropics. Grain oats are used widely as animal feed as well as for human consumption, grazing and conservation.

Common oat (*A. sativa*) cultivars are by far the most widespread. *A. byzantina* is adapted to warmer, subtropical conditions, while the bristle-pointed oat (*A. strigosa*) is adapted to poor soils and low summer temperatures, and has been cultivated for grain and straw in the more mountainous parts of northern Europe and in places in eastern and central Europe, where conditions do not suit the common oat.

Figure 15. A good crop of multi-cut oats on a small farm (Punjab, Pakistan)



Numerous cultivars are available to suit many agro-ecological conditions and different uses. Fodder oats which provide several cuts have been developed.

Oats may be grown in mixtures with annual, twining legumes such as peas and vetches, but it is essential that the growth cycles of the two crops match, otherwise the legume will have dried and shattered before the oats are at the cutting stage. Oats are a very useful "nurse" crop to grow with winter clovers such as Egyptian clover (berseem) (*Trifolium alexandrinum*) if used at light seed rates so as to give the establishing clover enough light to grow; the faster-growing and more cold-resistant oats provide early cuts at a season when green feed is scarce and clover growth stopped or very slow.

The time of sowing varies widely, according to the wide range of climates where oats are grown. In areas of very cold winters, they are spring sown; in temperate climates, both autumn and spring sowing occurs; in the Mediterranean and subtropical regions, they are mainly autumn-sown for hay; in the high altitude tropics, they are sown at the onset of the rainy season.

Local practices regarding seed rates and mixtures vary widely, and rates range from as low as 60 kg/ha to over 100 kg/ha.

Oats are often mixed with vetches, and sometimes peas, for hay or silage, as the cereal gives support to the trailing legume. However, the oat seed rate should be reduced by about half the normal for a pure stand, and the growth cycles of both crops must synchronize. A light seeding of oats is useful to give an early bite in Egyptian clover (berseem).

Single-cut types are mown after flowering, but multi-cut types should be cut earlier to encourage further growth. Mowing and hand-cutting are easy and the crop gives few problems in the making of hay. With a single-cut crop, it should be mown once the grains are formed; multi-cut types should be mown just prior to flowering, and the ultimate cut should be when the grain is well formed.

Oats are largely self-pollinated, so farmers can save their own seed for several crops, provided that rogueing is carried out and the usual precautions taken against mechanical contamination. The closely-related wild oats (*A. fatua, A. ludoviciana)* are serious weeds of cereal fields and care should be taken to avoid their presence in cultivated oats since the wild ones shed their seeds before harvest and would, thereafter, cause much damage in subsequent wheat crops. The introduction of fodder oats for demonstration purposes in the Kandahar region of Afghanistan was refused by the farming community because of their detestation of the wild oat.

Barley

Hordeum vulgare

An annual cereal mainly grown for its grain, which is widely used as food, for beverages and as stock-feed. Barley is used in temperate and subtropical countries as a fodder and hay in areas which are too dry or on soils too alkaline for oats. Barley is not as good as oats for hay or for grazing, but is valuable for dry, very high, or saline sites. Rough-awned barleys are less palatable than other cereals, and may cause damage to the mouths of livestock. It is sometimes sown, at reduced seed rates, in mixture with vetch or red clover. Autumn-sown barley, under Mediterranean conditions, may be grazed in late winter and early spring, and provided grazing is not prolonged too long the crop will give a satisfactory seed yield. Cultivation and haymaking is as for oats.

Barley is more drought-resistant and faster maturing than oats, and may be preferred on light, dry or saline soils. It is widely used for fodder in western and central Asia. Naked barley, which threshes free of the glumes, is grown at very high altitudes in the Himalayas, and on the Qinghai-Tibet Plateau, it is grown at over 4 000 m in the Lhasa river valley, well above the limit of spring wheat.

Rye

Secale cereale

An annual widely used for winter pasture in North America and as a minor cereal in parts of Europe. It is adapted to poor soils and severe winters.

Wheat

Triticum aestivum

Wheat is the most important cereal of temperate areas, and worldwide only second to rice. It is the preferred food throughout most of the temperate and subtropical areas. Wheat-rice rotations cover large parts of the Asian subtropics, with rice as the summer crop. Wheat straw is an important fodder throughout these areas. It is not widely grown specifically as fodder but is often grazed in winter in areas where this is possible, and then allowed to grow on for grain. In parts of the Himalayan region it is cut as fodder in time of scarcity, but is less productive than oats. Replacement of wheat-cutting by good fodder oats could improve productivity in many mountain areas in Asia. Drought-affected crops are often taken as hay or green feed. Wheat straw is an important fodder in small-scale farming areas.

HAY FROM COARSE GRAINS

Maize, some of the millets and sorghum were at one time dried as hay on large-scale farms, but with the development of modern silage making techniques such haymaking has almost disappeared and the coarse cereals, especially maize, are major silage crops. In small-scale farming, however, some are still made into hay; when the heads are hand-harvested for grain and the still-green stover dried for fodder as frequently happens, the dividing line between stover and hay is not a very clear one. Maize and grain sorghums are usually sown by spot planting, either by hand, by hand-fed single-animal-drawn drill or by a planter which drops seeds at spaced intervals - usually through a plate-feed mechanism.

Maize

Zea mays

Maize, known as 'corn' in North America, is grown wherever summers are warm enough and rainfall or water supply adequate. It is important as fodder, the grain is widely used in livestock feed, the stover is fed to livestock, especially in the developing world, and the crop is grown specifically as fodder on a large scale. Tropical maizes may reach four metres in height; those in temperate and subtropical areas are mostly under two metres. It is the supreme silage crop, but is sometimes dried as "hay."

Maize for fodder is harvested at a slightly less mature growth stage than for grain (about two weeks pre-maturity, but with the grains fully formed but not quite hard; the greater part of the digestible energy is in the cobs and grain) and is now often grown for silage in areas where a seed crop would be risky. Maize is widely used as a fodder catch-crop in subtropical irrigated areas; it is broadcast thickly and the cultivar is of little importance.

Maize has a very large number of cultivars and hybrids with different maturity periods, and it will grow under a wide range of agro-ecological conditions, but requires high temperatures for good growth. Locally-adapted hybrids, where available, are far higher yielding than open-pollinated selections. It is mainly grown in the warm temperate and humid subtropical zones. In the tropics, it can be grown up to about 3 000 m elevation, but is better below 2 400 m. Maize does not tolerate waterlogging and requires high fertility, but within these very wide limits it can be grown in most fertile soils. Cultivars to fit a wide range of rainfall patterns are available. Maize is not drought resistant (although it can stand some drought when young), and drought-escaping short-duration types have been developed for areas with short rainy seasons.

Maize should be sown in lines into a well-prepared seed-bed. Row and plant spacings depend on cultivar and fertility level. It is often hill-sown, either with a precision seeder or by hand, and 80 - 120 cm is the main row-width range, but may be closer under irrigation with small cultivars. Plant populations are between 25 000 and 75 000 plants per hectare. It is very important to obtain a full and even stand, and therefore the seed should not be broadcast. Sowing with a wheat drill often leads to uneven stands, so a specialized drill, or hand sowing, is to be preferred. Since spacings are wide, maize is easy to sow by hand where the areas involved are not too large; various simple funnel-and-tube arrangements on traditional animal-drawn ploughs are used with success by experienced farmers.

Choice of cultivar is very local and information on that, planting times, spacings, etc., should always be sought locally. Fertilizer application, both in the seedbed and as top-dressings, is necessary for a heavy yield; maize is not a crop for poor or worn-out soils. Weed control is essential from the outset, until the plants shade the inter-row. Maize is a monoecious, diclinous, wind-pollinated plant, so selection of open-pollinated cultivars has a limited effect. Hybrids, where available, have a far higher yield potential than open-pollinated seed. Hybrid seed can only be produced by organized enterprises and has to be purchased by farmers. Although the isolation distances required for hybrid seed production are large, it is possible to produce it under small-scale farming conditions if a whole geographical group or village agrees - as is done commercially in parts of China.

"Corn fodder" - dried maize grown specifically as feed - was at one time cut with a corn-binder, field dried and stored as hay, but this has probably been replaced by ensiling in mechanized farming. It still is widely used in India and Pakistan as *kadbi* (with sorghum and bulrush millet, as well as maize); the stalks are hand-cut, dried on the field, bunched and stacked upright, and this system works well where there is a long rainless season after harvest. In USA and southern Africa, the whole plant, with the cobs and grain, is sometimes harvested dry and ground as feed on large-scale farms where livestock are important.

Sorghum

Sorghum bicolor

Sorghum - a tall, clump-forming, tillering annual or short-term, ratooning perennial with culms up to at least 4 m high - is fourth in importance among the world's cereals, and is also an important fodder. It is widely grown in the drier parts of Africa and Asia for human consumption; it provides good malt and is important in brewing in parts of Africa and, notably, China. Its stover is a valuable feed, fuel and building material. In dry, hot areas of developed countries, it is grown for stock-feed. It is, however, susceptible to bird damage and has a big bird-scaring labour requirement under savannah conditions: maize is often preferred, in Africa, by small-scale farmers, despite the risk of crop loss in a drought year.

Sorghum has a very wide range of adaptation and can produce a grain crop under conditions which are unfavourable for maize and most other cereals. It can be grown on poorer soils and in drier climates than maize. It thrives on heavy soils, including cracking clays, even with temporary waterlogging. Even in the seedling stage, sorghum is drought-hardy and suited to areas of unreliable rainfall. Seedlings can survive wilting for at least two weeks and then recommence growth. The rainfall range is 400 - 755 mm. It is a crop for hot to warm conditions, and is killed by frost. Under equatorial conditions, it can grow up to about 2 200 m above sea level, although most is grown below 1 000 m, but traditional, cold-tolerant types are used at much higher elevations in Ethiopia. Its latitudinal range is 40° on either side of the Equator. Its range of pH adaptation (5.0 - 8.5) is wide; it withstands salinity better than maize. Sorghum is a short-day plant with marked response to photoperiod, so cultivars must be chosen accordingly; sorghums which grow tall as a summer crop may flower as dwarfs if grown in the shorter days.

Cultivated sorghums can be classified in five groups:

- ***Grain sorghums*** are grown principally for grain, but may be used as fodder.
- ***Sorgos***, the stems of which contain sweet juice, are used on a small scale for sugar making in Asia; they are grown as fodders, especially in the USA and are used in the development of fodder hybrids. While grain sorghums are frequently used as fodder, in more intensive production specially developed fodder cultivars are used - usually crosses between grain and sugar sorghums. These have a higher sugar content than ordinary sorghums and are less liable to cause prussic acid poisoning.
- ***"Grass" sorghums*** are species used as fodder (see below), of which Sudan grass (*S. drummondii* (syn. *sudanense*), Columbus grass (*S. almum*) and Johnson grass (*S. halepense*) are among the most important.
- ***Broomcorns*** (used in brush-making) and ***special-purpose sorghums*** (grown for starch making or pop-sorghum) have no importance as fodders.

All sorghums may contain a cyanogenic glycoside, dhurrin, which can be toxic. The danger is greatest in young re-growth, either from the base or from old stems. Care should be taken before putting stock to graze on sorghum aftermath, especially when it is drought stressed. There is no danger once the herbage has been made into hay, nor is the stover toxic.

A well-prepared seedbed gives an even stand, essential for good fodder production. Since sorghum is parasitized by plants of the genus *Striga*, it should be sown in rotation, avoiding over-frequent use of the same land. The seed may be broadcast, hill-sown or drilled, but drilling is the most satisfactory for hay. Seed rates are of the order of 7 to 10 kg/ha (much lower rates are used for grain in dry areas). The young crop should be weeded; a later weeding should be done where *Striga* is present, but before the parasite has had time to shed seed. As with all cereals, seed production is straightforward. Sorghums are cross-pollinated, but also self-compatible. Sorghum fodder is often grown as a summer catch-crop in India and Pakistan; any available grain sorghum is broadcast at a high seed rate, during the monsoon, and cut as required, or mown and dried when the field is needed for another crop.

Sorghum is cut when the grains are formed, and then tied into bundles, stooked and field dried before storage. In the USA, sorghums with sweet stalks are considered to be the best for hay, and known as sorghum fodder. Sorghum hay is mainly made by hand in India and Pakistan. At one time in the USA, a corn binder was used. Sorghum hay should be chaffed before giving to livestock to avoid wastage.

Other sorghums for hay

Sudan grass

Sorghum drummondii (syn. *sudanense*)

A tillering, erect annual with slender stems up to 3 m high, developed in the USA as a fodder from Sudan material. It is now widespread in the dry tropics and subtropics and in temperate regions with hot summers. It is used for both hay and grazing, but there is some danger of prussic acid poisoning when grazed, especially if plant growth is checked; dry-season aftermath from seed crops is dangerous. It does not spread naturally and can be grown in arable rotations without danger of becoming a weed (*cf S. halepense*). It is now being replaced by interspecific hybrids in areas of intensive agriculture where hybrid seed is available.

Sudan grass is suited to areas with a hot growing season; it does not thrive in the humid tropics nor in cool, humid temperate conditions. Rainfall of 500 - 900 mm/yr suits the crop and it is frequently grown under irrigation. It will grow on a wide range of soils provided that they are not waterlogged, and it is moderately tolerant of salinity. In the equatorial tropics, it can be grown up to 2 000 m elevation.

Seed is drilled or broadcast into a firm seedbed at a depth of 1 to 3 cm. Seed rates vary widely, from 15 kg/ha in wide drills for low-rainfall areas, to 75 kg/ha in irrigated land. Row-planted crops should be cultivated for weed control. Fertilizer must of course be applied according to local needs. Sudan grass is a heavy seeder and can be harvested with a combine harvester; it can also be dried in stooks and threshed with a stationary thresher. Seed can be harvested from closely sown hay stands, but where seed is the main product it should be grown in widely spaced (60 - 90 cm) rows. It is cross-pollinated.

When harvesting as hay, Sudan grass recovers well after cutting and three or four cuts can be taken in one year, with more from irrigated crops. For hay, it is cut from flowering to the milk stage, at a height of 10 - 15 cm. A top-dressing of nitrogenous fertilizer is usually applied after each cut except the last. Conditioning of the forage to allow better stem drying is useful. It is made into hay in hot, dry areas where curing of the rather coarse herbage is not a problem.

Columbus grass

Sorghum almum

A tufted perennial, 1 - 3 m high, which originated in Argentina. It is used in the USA and in Australia as a pioneer crop in pasture development and for hay. It is adapted to warm areas with a rainfall of 450 - 750 mm/yr; it is susceptible to frost but will re-grow from its rhizomes after light frost.

Johnson grass

Sorghum halepense

A rhizomatous perennial, similar in many respects to Sudan grass, probably of Mediterranean origin, but its natural distribution extends east to India. It is adapted to areas of hot summers with rainfall of 500 - 750 mm/yr, and is cut back by frost, but re-grows from its rhizomes. Because of its long, robust rhizomes, it is a serious weed of arable land. It was introduced to the USA as a fodder crop in the early nineteenth century, and soon became a serious weed in some areas. It can be sown as for Sudan grass, or established by discing in rhizomes. Johnson grass produces good hay from naturally occurring stands, but is rarely established intentionally. Haymaking is as for Sudan grass.

Hybrid sorghums

Commercial hybrid fodder sorghums are now available, usually based on Sudan grass and grain sorghum. The male-sterile cultivar Redlan is frequently one parent. Most are F1 hybrids, so entail annual purchase of seed. They retain the multi-cut qualities of Sudan grass but have a much higher yield potential. These hybrids are suitable for both irrigated and rainfall conditions. Their cultivation is similar to that of Sudan grass, although low seed rates are often used because of cost. They are becoming popular for green fodder in some developing countries, notably in the irrigated tracts of Pakistan, where they have expanded greatly in the past ten years, partly due to the availability of imported seed. Apart from their high yields, long production season and good fodder popularity, they have the advantage over single-cut sorghum in monsoonal areas in that, sown well before the rains, they can provide several cuts without having to try to work land and sow during waterlogged conditions; only top-dressing after cutting is required. Seed is widely available internationally, but local production of hybrid sorghum seed is a specialized undertaking that is only worthwhile where the potential market is sufficiently large.

Millets

Many crops are referred to as "millet" so, in referring to literature, care should be taken to ascertain which species is being referred to. Bulrush millet is the one most commonly grown as a fodder in tropical and subtropical regions; some others may occasionally be grown as fodder; the straw of all is used. Foxtail millet (*Setaria italica*) and common or proso millet (*Panicum miliaceum*) are the common millets of northern China and many mountainous areas. Finger millet (*Eleusine coracana*) is important in parts of India and Africa. *Echinochloa frumentacea* is cultivated as a summer fodder in some countries, including India and Pakistan (where it is known as *swank*). Proso millet is rather too hairy to make palatable hay, but foxtail millet is sometimes grown for hay in the USA.

Bulrush millet

Pennisetum americanum

A tall, tillering annual, growing to 3 m, which is widely grown as a staple in the drier areas of Africa and India. It can produce a crop on poorer soil and lower rainfall than can maize or sorghum. In India, Pakistan, South Africa, and the USA, it is also grown as fodder. The straw is coarse, pithy and of low feeding value. It is very susceptible to bird attack. Some special fodder cultivars have been developed.

Bulrush millet is mainly grown in semi-arid regions on light, well-drained soils. In the Sahelian zone of Africa, it is grown under rainfalls as low as the 250 mm isohyet; for sown fodder, however, 500 mm of rainfall is needed for a good crop. While it can be grown on lower rainfalls than sorghum, it does not have the latter's facultative ability of going dormant during drought spells. It requires high temperatures; in the tropics it can be grown up to 1 500 m. On heavy soil where waterlogging might occur, it may be grown on ridges. It will grow on a wide range of soils and can produce a modest yield on land too poor to support better cereals. In India and Pakistan, it is sometimes irrigated. It is tolerant of salinity.

As a rainfed cereal, bulrush millet is often grown in mixed stands; for fodder, however, it should be grown pure. Seed rates vary from 3 to 9 kg/ha, the lower rates being used in India. Seed may be drilled or broadcast, and later thinned. For hay, a much denser stand than for grain is desirable as stems will be thinner. The vast bulk of millet seed is saved by the farmers; it is a mainly cross-pollinating crop; yields are high and the seed stores well.

For haymaking, the crop should be cut at the milky stage, before the stems become woody, and then tied into sheaves and dried in the field.

GRASSES FOR HAY

Rescue grass

Bromus catharticus (syn. *unioloides*)

A tufted, short-lived perennial from temperate and subtropical areas of Latin America, now cultivated in several subtropical and warm-temperate countries, and mainly used for hay. Its productive life is usually about two years. It is not invasive and is suitable for use in arable rotations.

It has a wide tolerance of soils and can withstand some frost. It is used in several warm and subtropical countries, including parts of New Zealand, South Africa and the USA. In the tropics, it has been used commercially at high altitudes in Colombia and (above 2 000 m) in eastern Africa. It was once popular in the Nakuru area of Kenya, but gave way to Rhodes grass, which, under those conditions, is longer-lived and more prolific.

It is easy to establish as its seeds are large and its seedlings strong, and can be drilled without difficulty. From 10 to 30 kg/ha of seed are used; in France, 50 kg/ha is recommended (Peyraud, 1985). It can be grown in mixture with lucerne, and with sainfoin and red clover in temperate areas. Rescue grass produces good yields of easily-harvested seed.

Rescue grass makes excellent hay and has no particular difficulties. This is a short-term hay crop and, apart from top dressing when needed, no maintenance should be required.

Buffelgrass

Cenchrus ciliaris

A tufted, tussock-forming perennial, with many ecotypes, some rhizomatous, from drier areas of the old-world tropics and subtropics, now widely introduced to other hot, dry areas. It is very persistent and withstands grazing well.

It is a grass of warm areas and, at the Equator, it does best below 1 600 m. It can be grown in areas with over 300 mm of annual precipitation and requires well-drained soil, preferably deep; the upper rainfall limit is about 750 mm. Buffelgrass is grown in areas too dry for more productive species. Palatability varies greatly between cultivars. Its drought resistance and persistence may be partly due to a deep and strong root system.

Fresh *Cenchrus ciliaris* seed has very poor germination, but this improves in storage, with a peak at about two years. It is easy to establish from seed, but must be sown into a properly prepared seedbed. The seedlings are large, robust and can withstand short periods of drought after germination. The fluffy seed is not easy to sow, does not pass through drills easily and tends to "bridge" in the seed-box. Care must obviously be taken at sowing to ensure even spread; the seed should be covered by a light harrowing. For grazing or seed-production stands, line-planting at 50 - 75 cm is simple and satisfactory, but leads to large tufts which are problematical for haymaking. For hay, a close, even stand should be aimed at. Seed is commercially available internationally. Fields reserved for seed should be mown or grazed until just before the season when good conditions for harvest are expected, then cut to even height and closed to let the seed crop grow. Harvesting is by hand or by machines, which beat the ripe seed on to collecting trays. Seed remains viable for two to three years.

Buffelgrass withstands mowing well and makes reasonable hay; it should be cut at the early flowering stage. It grows in areas where drying is usually easy.

Buffelgrass responds to nitrogenous fertilizer but, in the semi-arid conditions under which it is grown, it is not often fertilized, except at installation. Slashing, to level the clumps, may be needed prior to growing it on for hay.

Rhodes grass

Chloris gayana

A stoloniferous, creeping perennial from tropical and subtropical Africa up to about 2 000 m altitude, which thrives under a wide range of temperatures and will withstand light frosts. It was introduced to cultivation in South Africa in the 1890s, and has since spread throughout the tropics and subtropics and become one of the most popular and widespread fodders as pasture and for hay. Rhodes grass is easy to establish and easy to eradicate, so does not become a weed in mixed farming systems.

Rhodes grass is drought resistant and will grow in areas of 500 - 600 mm annual rainfall; its preferred range is 750 - 1 500 mm; it is not well suited to very high rainfall areas. It grows under a wide range of soil conditions, except those which are very heavy or very acid. Its salt tolerance is high, and it can be used under irrigation on desert soils too alkaline for lucerne. Where salinity is irregular, some Rhodes grass seed can be added to lucerne and will cover patches too salty for the legume.

In pure stand, 0.5 to 1.0 kg/ha of pure germinating seed is adequate for a pure stand. It can be easily propagated vegetatively, with pieces of rooting stolons. Its ease of establishment probably has much to do with its popularity. The very small seed is enclosed in a light floret; care at sowing is necessary to avoid wind drift and to ensure only the lightest covering of the seed. Seedling growth and development is rapid and a cut can be expected, given adequate moisture, in six to eight weeks.

The crop is most productive in the first two or three cuts, unless it is heavily fertilized. Crop life is three to five years. Seed production is easy; but, as it is a cross-pollinating plant, different cultivars of the same ploidy should be separated by at least 200 m. Crops specifically sown for seed are usually row-planted; nitrogenous fertilizer should be applied to seed crops at up to 100 kg/ha N. Heads can be harvested by sickle when hand-rubbing shows that a good number of ripe and fully-filled caryopses are present; the cut heads are carefully transported, dried and threshed. Seed will germinate soon after threshing, but germination improves over several months, reaching a peak at one year. Rhodes grass seed stores well and will keep at least three years. Seed is produced commercially in several countries, and Australia and Kenya are big producers. It is one of the most readily available tropical grasses.

Rhodes grass leaves and stems are fine, and it produces uniform herbage in even stands, while its stoloniferous growth habit leaves a level base for haymaking operations. It is easy to make into hay and can be handled with standard techniques.

The crop should be grazed when the weather is not suitable for haymaking; it may be slashed level before setting aside for hay and a top-dressing of nitrogenous fertilizer applied. Rhodes grass recovers well from fire, so old fields with a lot of dry herbage and weeds can be burnt at the onset of the rains.

Bermuda grass, African star grass, giant star grass

Cynodon dactylon, *C. nlemfuënsis* and *C. aethiopicus*

Until the revision of the genus in 1970, the two species commonly used in agriculture were referred to as *C. dactylon* and *C. plectostachyus*, so older references in the literature are misleading. *C. dactylon* is the strongly rhizomatous plant common in the subtropics and warm temperate areas; it is now recognized that it rarely occurs in the tropics. *C. nlemfuënsis* and *C. aethiopicus* - both stoloniferous perennials without rhizomes - are the common African pasture types, with the former being by far the most widespread. Earlier references to *C. plectostachyus* mainly refer to *C. aethiopicus* (see Bogdan, 1977), and also *C. dactylon* was formerly used for small- and medium-sized types from Africa.

C. dactylon is widely used in the warmer parts of the USA and is an excellent hay grass. Coastal Bermuda is one well-known cultivar, and more have been developed in the USA. Because of its rhizomatous habit, *C. dactylon* is a serious weed in arable areas. The African species are widespread in the subhumid to semi-arid regions but, since they are plants of the good soils, few large areas of *Cynodon* grassland remain in Africa as those areas have mostly been developed for cropping (e.g., the foot slopes of Mount Kenya). The African species have no rhizomes so are suitable for pastures.

They tolerate a wide range of soils and will stand some waterlogging; *C. dactylon* will survive long periods of immersion. For good yield and persistence, especially by African types, soil fertility must be maintained. They are drought-tolerant but can thrive in high rainfalls with a range of 600 - 1 750 mm/year. *C. dactylon* survives frost because of its rhizomes. It has good salinity tolerance.

Star grass is a poor seeder, but easily established by splits or sods. Plant at 1 m x 1 m into moist soil when rain is expected.

Star grass makes excellent hay and is easy to cure.

Once established, star grass resists weed invasion well and is persistent; it does, however, require regular top-dressing with nitrogenous fertilizer and, for hay, with complete fertilizer. It should be grazed during weather unsuited to haymaking.

Cocksfoot

Dactylis glomerata

A tufted, long-lived, deep-rooted perennial which tends to form large tussocks. It is native to Europe, North Africa and temperate Asia, but has been introduced to temperate areas throughout the world. It is a grass for long-term leys, and should be used for fields meant to last over four years. It combines well with legumes since it is slow to establish but, later, must be carefully managed so that it does not shade them out. In the USA, it is the preferred companion grass for white or ladino clover.

It is well adapted to cool temperate conditions, being more cold tolerant than ryegrass but less so than timothy (*Phleum pratense*); it stands up well to high temperatures and drought. Cocksfoot prefers loams and clays, but will survive and produce on light soils; it is less fertility-demanding than ryegrass. As would be expected with a plant with so wide a distribution, it has a wide range of ecotypes with widely differing climatic adaptations. Mediterranean ecotypes can exhibit dormancy during the long, dry, hot summers. In the tropics, cocksfoot can be grown successfully at altitudes over 2 250 m.

It is drilled or broadcast. When sown in pure stand, 5 to 10 kg/ha of seed should be used.

Cocksfoot is a major hay plant in North America, and standard techniques apply.

In mixtures with clovers and grown for hay or silage, it is impossible to maintain the legume if the crop is only mown. Hard grazing in spring to encourage legume growth is essential, before allowing the crop to grow up for mowing.

Weeping lovegrass

Eragrostis curvula

A tufted perennial with narrow leaves with inrolled margins, originating in eastern Africa. It is the most important hay grass in South Africa, and is grown in the USA and used for winter pasture in Florida. Palatability varies between cultivars, but it is generally well accepted when young.

It is a warm-season plant which withstands high temperatures and tolerates light frost. It can be grown with rainfalls from as low as 500 mm/yr up to 1 000 mm/yr and is drought tolerant. It prefers light soils but will thrive on most if well-drained. It is very tolerant of salinity and grows on soils of pH up to 8.5. It survives on poor soils, but for high production it requires fertilizer and extra nitrogen.

A firm, well worked seedbed is desirable. Seed should not be covered by more than 0.5 - 1 cm. *E. curvula* is easy to establish and is often sown under a nurse crop of teff in South Africa. Seed rates of the crop and nurse crop vary according to rainfall and sowing method. South African recommendations are: for areas with 650 mm/yr rainfall, 2 to 4 kg/ha *E. curvula* + 5 kg/ha teff; for 900 mm rainfall, 5 kg/ha *E. curvula* + 8 to 10 kg/ha teff; for low rainfall, broadcast, 2 to 4 kg/ha *E. curvula* + 4 to 6 kg/ha teff; for low rainfall, row planted, 2 kg/ha *E. curvula* + 5 kg/ha teff; for high rainfall, broadcast, 6 to 8 kg/ha *E. curvula* + 8 to 10 kg/ha teff; and for high rainfall, row planted, 3 kg/ha *E. curvula* + 6 kg/ha teff.

It is sometimes grown in mixture with lucerne. *E. curvula* seeds heavily and may be harvested with a header when a third of the seeds have turned brown. The threshed product is caryopses, not florets. High seed yields are obtained from row-planted crops. It is an obligate apomict.

It is easy to dry, with its fine leaves, and makes good hay if cut before it becomes too coarse.

Teff

Eragrostis tef

An annual grown widely as a cereal in upland Ethiopia at altitudes of 1 700 - 2 800 m, where it is the preferred grain. It has been tried in many tropical and subtropical countries for hay, since it establishes and grows rapidly and can produce a hay crop in 9 to 12 weeks from sowing, but has only become popular in southern Africa. It can be grown in dry areas because of its short lifespan, which allows it to escape droughts. The only country outside Ethiopia where teff has become an important crop is South Africa, where it is a major hay species, but it is also used as pasture in the southern coastal regions of the Cape. Teff was introduced to South Africa in 1886 and its hay proved very palatable to race horses, so a demand grew. It a rainfed crop. The traditional sowing date in South Africa is November, but trials at Cedara indicate that earlier (September/October) sowing may produce higher herbage yields, as early sowings gave 8 to 9 t/ha DM whereas November sowing yields between 3 and 4 t/ha. It is grown in all but the driest parts of South Africa and is probably the second most widely used hay after *Eragrostis curvula*; it is grown in pure stands (and as a nurse crop for *E. curvula*). In the dry Karoo, hay is grown on the bottom lands. Area statistics are not available, but about 1 000 t of teff seed are sold annually through seed companies; this does not include farm-to-farm sales. Teff hay is primarily a horse feed, but is used more and more for dairy cattle and wild animals due to its high palatability and digestibility. All wild game that the Natal Parks Board captures for relocation or sale are fed teff hay while held in captivity.

Teff is a summer crop that is tolerant of most soil types and a wide range of rainfall conditions, provided that it rains during its short growing season. Fertilizer levels in Natal are 10 ppm P and 140 ppm K.

For hay, seed rate recommendations vary considerably: between 5 and 15 kg/ha sown broadcast on a well-prepared, firm seed-bed. The general South African recommendation is that the seedbed should be rolled before and after sowing. Germination and growth are rapid; for hay the crop is not thinned. Teff is a cereal, seed production is therefore easy and yields are high. A seed crop, unlike a hay crop, should be thinned and weeded; the seedlings are tiny, so this must be done with care. The seed threshes without adhering glumes, so cleaning presents no difficulties. It is said to be a self-pollinating apomict.

Teff is mown at flowering and is easy to handle, with thin leaves and stems. The crop should be cut at the flowering stage but before seed set. It is important to mow before it begins to lodge, which is usually soon after flowering begins, depending on weather conditions. Lodged teff is difficult to mow and leads to wastage. Weather permitting, teff can be mown, dried and baled the same day in South Africa. If the stand is thick it may be necessary to turn the cut material once for better drying.

Teff is a short-term crop. In South Africa, early-sown teff is cut several times, while late-sown crops are cut only twice. Crops late-sown after a well-manured previous crop are usually given no fertilizer. However, where several cuts are taken, nitrogen, and probably potash, are required, since large amounts of potash are transferred when the cut material is removed from the field.

Excessive nitrogen application only promotes lodging, so any added production due to the extra fertilizer is lost through wastage during mowing.

Tall fescue

Festuca arundinacea

A tall, tussock-forming, long-lived perennial which forms a sward if grazed. It occurs naturally in Europe, North Africa and temperate Asia, and has been widely introduced in other temperate regions. It is a good companion for legumes and can make high quality hay. Some strains have symbiotic fungi which produce mycotoxins.

It has a wide range of ecotypes adapted to a wide variety of soils. It is especially valuable for low-lying land with seasonal waterlogging, and in the Mediterranean area it occurs naturally under such conditions, often with strawberry clover (*Trifolium fragiferum*). At the same time, tall fescue is deep-rooted and drought resistant, and can survive in regions with under 400 mm annual rainfall, and thrive on dry, calcareous soils.

It is slow to start and requires a clean seedbed, since the seedlings do not compete well with weeds. Careful seedbed preparation, in advance of sowing, with harrowing to destroy the first growth of weeds, may help. Drill at very shallow depth, or broadcast and cover lightly, at 10 to 25 kg/ha for pure stands. A full stand is important to reduce the occurrence of coarse tussocks. It is relatively easy to establish legumes with tall fescue because of its slow initial growth; once established, however, it is a very aggressive grass and careful grazing and mowing management will be necessary if the legumes are to survive.

In terms of haymaking and sward maintenance and management, standard techniques apply.

Italian ryegrass

Lolium multiflorum

A vigorous annual or biennial from southern and western Europe, North Africa and southwest Asia, which is now cultivated widely in temperate and subtropical regions. This is a long-domesticated grass, very widely used for hay. It is used for pasture, hay and silage for up to two year's duration. It combines well, at light seed rates, with Egyptian clover (berseem) and gives early bulk at a time when the clover is barely growing because of low temperatures. Westerwolds ryegrass, a fast growing, strictly annual form, useful for hay, should be sown early in the year and, as it flowers profusely in the seeding year, grazing and mowing should be arranged to keep the herbage leafy.

It suits mild, humid climates and well-drained fertile soils, and grows well under irrigation. It does not withstand very harsh winters or poor soils. It grows well in subtropical winters, often producing green feed when traditional crops are dormant.

Italian ryegrass is easy to establish. It should be drilled or broadcast into a well-prepared seed-bed at 10 to 15 kg/ha in pure stand. In mixture with red clover (*Trifolium pratense*) 5 kg/ha of ryegrass is used. It is used to give bulk and ground cover in mixtures of longer-living grasses, but then must be used at very low seed rates or its vigorous early growth will suppress the more valuable, longer-lived grasses and legumes. The seed is shallowly drilled into a firm seedbed in the usual way. Seed is readily available in world trade. Supply is, however, a problem in some subtropical countries, where it would combine well with Egyptian clover to help cover the winter gap.

This is a major hay grass and standard techniques apply.

The grass is usually grazed at the start of the season, then fertilized and laid up for hay to be ready at the season of prime haymaking weather. Top-dressing rates should aim at the maximum crop which will not lodge.

Perennial ryegrass

Lolium perenne

A loose to densely-tufted perennial which forms a dense turf when grazed, It originates in the temperate zones of Europe, North Africa and Asia. It is the major pasture and hay grass of western Europe, and is very important in New Zealand. Hybrids with *L. multiflorum* are also cultivated; they are longer-lived and are used to increase yield in the first two seasons of a ley's duration; they have good winter production in mild areas.

Perennial ryegrass is a crop for mild, humid-temperate climates and rich soils; there are also Mediterranean, summer-dormant ecotypes. It is not suitable for poor soils or very warm summers. A wide range of cultivars and strains are available; hay types are taller and more erect than pasture types. It can be grown at high altitudes in the tropics, and has been very successful, such as in Kenya, if fertility is maintained at a high enough level. It is not suited to dry conditions or infertile soils. Perennial ryegrass and white clover is a classic mixture for grazing under humid temperate conditions; it is not, however suited to poor soils and hot summers on acid soils under subtropical conditions. It can be grown in the subtropics and high-altitude tropics, but only if well fertilized. Attempts in development projects to use it for re-seeding on poor soils (usually along with white clover), outside its zone of main use, however, have usually failed after a season or so.

Recommendations for seed rate and establishment vary very widely. Ten to twelve kg in a mixture with clovers was a common recommendation, but some European recommendations now go up to 30 kg, although this must give problems with legume installation unless early management is very carefully done. In the high altitude tropics, very low seed rates have to be used if legume establishment in mixtures is to be attained. Morrison (1966), working in Kenya, stated

> "When clover was sown in the conventional British and New Zealand mixtures in which the companion grass is sown at 15-25 lb./acre, clover frequently failed to persist beyond the establishment year ... The choice of companion grass is important. *Lolium perenne*, which establishes very rapidly, has proved to be an unsatisfactory companion grass for legumes at high altitudes except when sown at less than 1 lb./acre. Slower establishing grasses, such as *Festuca arundinacea* and *Dactylis glomerata*, have proved to be satisfactory companion grasses for subterranean and Louisiana white clover."

Perennial ryegrass is very frequently mixed with white clover at 2 kg/ha, and, for hay, red clover is frequently included. Seed of perennial ryegrass is widely available commercially.

For haymaking, standard techniques apply.

Establishing stands should be lightly grazed to encourage tillering, suppress weeds and encourage legume development. Grazing (or harvesting as silage) should be so timed that the crop reaches the correct stage for haymaking at a season when the weather should be suitable for curing. Regular applications of maintenance fertilizer and nitrogen should be applied, with the nitrogen dose calculated to give a heavy, but not lodged, crop. Grazing too early in spring and poaching in winter are to be avoided; under cool humid conditions, an early application of nitrogenous fertilizer in early spring will produce valuable grazing several weeks ahead of the natural flush.

Coloured Guineagrass or kleingrass

Panicum coloratum

A tufted, erect or spreading perennial, 50 - 150 cm in height, from tropical and subtropical Africa. It is hardy, easy to establish and well suited to seasonally waterlogged lands which are difficult for arable, but it has not yet been much used commercially. Cv Solai - selected in Kenya - was at one time commercially available. Makarikari grass (*Panicum coloratum* var. *makarikariensis*) is a stoloniferous plant with bluish leaves; it has been widely used for soil conservation in eastern Africa, as well as as a pasture plant. Named cultivars include Bambatsi, Bushman mine and Pollock.

It is a warm-season plant which will grow on a wide range of soils, including black clays. It tolerates waterlogging well and is moderately resistant to salinity. In eastern Africa, it is found at altitudes between 1 100 and 2 000 m in areas with over 500 mm/yr rainfall.

The seed of *P. coloratum* often exhibits dormancy when freshly harvested and may have to be scarified or stored for some time before sowing. Seedling vigour is good and seed may be covered to a depth of 1 - 1.5 cm. A reasonable seed rate is 0.5 to 1 kg/ha of PGS.

It is a good hay plant and easy to cure, but should not be allowed to become too mature before mowing, as some cultivars rapidly become woody.

The crop should be grazed until such time as it is set aside for hay, with fertilizer top dressing as appropriate.

Guineagrass

Panicum maximum

A large, very variable, tufted perennial of African origin, up to 4.5 m in height. Stoloniferous types are known. It is now widely introduced to tropical countries. *P. maximum* var. *trichoglume* - slender Guineagrass or green panic - is a smaller variety which is widely cultivated, especially in tropical Australia. The main areas of Guineagrass cultivation are in Latin America. It is an excellent grazing grass but, for haymaking, its tufted habit is not ideal and care must be taken in establishing and maintaining a full stand, otherwise hay handling on a tufty base is problematical.

It is a plant of frost-free, tropical conditions, although it will recover from light frosts. Guineagrass will tolerate a wide range of well-drained soils, but is only really productive under conditions of moderate to high fertility. Its rainfall requirements vary widely according to ecotype. It occurs in the wild in the semi-arid tropics in areas with 500 - 600 mm rainfall, but the larger cultivated types generally require 800 - 1 750 mm to do well. It has little tolerance of salinity.

Freshly harvested seed may exhibit dormancy and should be stored for some time before use. For hay, it should be close-drilled or broadcast at 1 kg/ha PGS. It combines well with some twining legumes, including centro (*Centrosema pubescens*) and this persists well in grazed stands, but would be less likely to do so where the crop is only mown for hay. The larger types can be easily established from splits when widely-spaced plants are acceptable for grazing or cut-and-carry, but this does not produce a suitable surface for haymaking. Seedling growth and vigour are only moderate, so it is usually necessary to let the crop become well established before heavy grazing; once established, it is long-lived and persistent. Seed of some Australian cultivars, especially of slender Guinea, is available in the international market. It seeds freely, but flowering and ripening are spread over a long period, seed sheds easily and harvest is difficult. Tying the heads into sheaves, without cutting, when many seeds appear to be ripening, cutting a week or two later, transporting carefully to a drying area, and then threshing, is a useful method where labour is abundant.

For hay, it must be mown before becoming too stemmy; the smaller types, like var. *trichoglume* and cv Makueni, are probably easier to handle.

Dallisgrass

Paspalum dilatatum

A leafy perennial, originating in the South American subtropics, with short rhizomes, and which forms spreading clumps with flower stems 50 - 150 cm tall. It is now widely introduced to tropical countries and others with mild winters and warm summers. It is cultivated and naturalized in many countries, including Australia and the USA. Dallisgrass is very persistent but combines well with white clover in subtropical conditions if hard grazed. Its palatability is moderate and declines seriously when its flowers are infected by ergot (sclerotia of *Claviceps paspali).*

It grows best on heavy, fertile, moist soils and requires high temperatures for growth, but survives frost and grows away from the rootstock when temperatures improve. It does best with over 1 000 mm/yr rain. Once established it can withstand long periods of drought because of its strong root-stock.

It is usually broadcast or close-drilled at 10 to 15 kg/ha. Clover can be sod-seeded into it, in subtropical areas, to give cool-season production when the grass is dormant in autumn.

Dallisgrass flowers are very prone to attack by ergot (*Claviceps* spp.) so where infestation is likely it should be mown for hay before heading, to reduce the risk of toxicity.

It should be heavily grazed to keep down flower-heads during the growing period, except when laid up for hay.

Reed canarygrass

Phalaris arundinacea

A robust, rhizomatous perennial up to 2 m tall, which spreads vigorously. It is widespread on moist sites in Europe, northern Asia, North America and South Africa, is a component of hay meadows in the Ethiopian Highlands, and is widely introduced into other temperate areas. It is a coarse grass that requires careful management to keep it at a palatable stage, but it can be grown on seasonally waterlogged or flooded land unsuited to other crops.

It grows best on moist, sandy soils rich in organic matter, but will thrive on fertile loams and clays, so long as moisture is adequate. It grows in a wide range of temperate to subtropical conditions, but is very cold-tolerant and is used in Canada and the Pacific Northwest. It remains green until after really hard frost.

It requires a clean, well prepared seedbed and is best spring sown, drilled at 4 to 7 kg/ha.

For hay, its coarse herbage is not easy to dry, and management should take this into account. Early growth is usually best grazed to encourage leafy re-growth; hay should be made once the season has warmed up sufficiently. It should be mown just as it comes into bloom.

Timothy

Phleum pratense

A tufted perennial originating in Europe and temperate Asia. It has been introduced to most temperate areas. Timothy is better suited to cutting than to intensive grazing, as its high palatability and rather slow re-growth puts it at a disadvantage in grazed mixtures. It is particularly important in Scandinavia and Canada, and is the main hay grass of northern USA, where it is often mixed with red clover.

A grass of cool to cold, temperate climates, it prefers deep, moist soils and tolerates wet conditions. It is useful under wet conditions and on heavy-textured or peaty soils. It is very cold tolerant and often remains green throughout winter.

It is usually sown under a spring cereal, at 5 to 10 kg/ha in mixture with clover.

Timothy is a major hay grass, but quickly becomes stemmy and should be cut before, or just at, ear emergence to assure high quality fodder. Early cutting encourages re-growth and stimulates the clover in mixtures.

The undersown crop is grazed lightly in autumn and then cut annually for hay, with its aftermath grazed. Top dressing of fertilizer is required for maintenance each spring. The proportions of N, P and K will depend on the emphasis put on maintaining the clover component.

CHAPTER VI
HAY CROPS - LEGUMES AND PULSES

LEGUMES

TREFOILS

Lotus spp.

Two of this large genus are used as pasture and hay crops, namely birdsfoot trefoil (*L. corniculatus*) and greater trefoil (*L. uliginosus* (syn. *L. major, L. pedunculatus* of authors)). They are fine-leafed, stemmy perennials with sessile leaves and showy flowers. Their pods are long and narrow. Trefoils are interesting for soils low in phosphate, in places where fertilizer is dear or difficult to transport.

Birdsfoot trefoil

Lotus corniculatus

A native of temperate Europe and Asia, it is used for pasture and sometimes hay. It is a hardy perennial with a strong tap root, procumbent stems and yellow or red flowers. It is also grown in North America, Australia, New Zealand and South America. It is more tolerant of poor soil, waterlogging, salinity (*cf* the case study on Altai) and high temperatures than the more important temperate clovers, but does not compete well with clover and lucerne where conditions suit them.

Cultivation is as for clover; the seed rate is 5 to 7 kg/ha in pure stand, but much less in mixtures. It is slow to establish compared to clover and is not suited to short rotation use. Seedling vigour is much less than that of lucerne or red clover and establishing stands can be lost through shading by competing crops or weeds. USA practice is reviewed in detail by Seany and Henson (1970), who recommend that hay fields should be managed to avoid very early or late autumn cuts. Birdsfoot trefoil is very prone to lodging as it approaches maturity, with consequent losses during mowing and curing hay; this is reduced if it is associated with cocksfoot or timothy. Viking is a popular cultivar in Canada, together with Empire, Leo and Maitland. It is usually mown for hay as the plants come into bloom. Potential seed yield is probably 600 - 1000 kg/ha, but harvest is not easy since the pods shatter explosively when ripe: field yields may be as low as 50 - 150 kg/ha.

Greater trefoil

Lotus uliginosus (syn *L. major* and *L. pedunculatus* of authors)

Greater or big trefoil resembles *L. corniculatus* and is used in the same way, but is much less winter hardy, does not withstand salinity or drought, and needs more moisture. It is grown on low, wet land, and in high rainfall areas of Europe, North America and New Zealand; it is naturalized and well established in the wet, temperate Andes. The New Zealand cultivar Maku has been used with success for pasture improvement on poor soils in wet conditions.

Lucerne, alfalfa

Medicago sativa

Lucerne or alfalfa is an upright, deep-rooted perennial with many, usually erect, stems which arise from crown buds. It is the world's most important forage crop and a high-quality feed for all types of livestock. Under suitable conditions, it is the most productive fodder legume, and probably the first fodder to be cultivated. It was grown in Iran in 700 BC, reaching Greece 200 years later. It spread throughout southern Europe, North Africa and Asia, and was taken to the Americas by the Spaniards, and later spread to the USA in the mid-nineteenth century. Lucerne reached China in the second century BC, when Iranian horses were acquired for military use. It only came into use in northern Europe and Australasia during the past two centuries. It is a common small-scale farming crop in the drier parts of Asia and North Africa; in some areas, the young shoots are traditionally used as a vegetable. Lucerne is noted as a soil improver, in both small-scale and large-scale farming. It is highly melliferous, and because of its many flowerings throughout the year, is of great potential interest to beekeepers. For warm, arid and semi-arid areas, a full treatment is given in the FAO publication by V.L. Marble (FAO, 1989).

It is a crop which requires low humidity and neutral-to-alkaline, well-drained soils, but can be grown on moderately acid ones. It does not, however, tolerate humid climates at high temperatures; its poor performance in humid, tropical and subtropical sites on acid soils has often been proven. Cultivars are available to suit conditions from the dry subtropics to the coldest limits of agriculture. For rainfed cultivation, a minimum of 500 mm per year of precipitation is required in subtropical regions, but in colder zones it can be grown on 300 mm. High rainfalls, over 800 - 1 000 mm, unless on very well drained, deep soils, are less suitable. Above 1 000 mm, soils are usually more acid and humidity greater, leading to more leaf disease, and there is danger of periodic waterlogging. Good, well-drained land with a deep root-run should be chosen to sow lucerne for hay, as rooting depth can be 3 to 5 m if moisture is not limiting.

Two main subspecies of *Medicago* are involved in the development of the wide range of lucerne cultivars now available: the purple-flowered *M. sativa* subsp. *sativa* is the standard form, and yellow-flowered *M. sativa* subsp. *falcata* (sickle-pod lucerne) which is rhizomatous and frost and drought resistant. *M. sativa* grows in more clement climates, south to the Mediterranean region. Where the distribution of the two forms overlap, hybrid forms arise, formerly identified as *M. media* or *M. varia*, but now known as *M. sativa* subsp. *varia*.

Cultivars may be classified into four groups according to origin and hardiness:

The Common group comprises pure *M. sativa* subsp. *sativa* types, with purple flowers and limited winter-hardiness. It is represented by the common lucernes of the USA and regional strains from central Europe, Argentina, South Africa, New Zealand and Australia.

The Turkistan group consists of *M. sativa* subsp. *sativa* types. Their growth habit is shorter and more spreading than the Common group. It has slow recovery after cutting, with low seed yield, but is resistant to cold and bacterial wilt.

The variegated group of cultivars, which have variegated flower colour and probably originated as hybrids between *M. sativa* subsp. *falcata* and *M. sativa* subsp. *sativa*. Most are winter-hardy.

The non-hardy group that is adapted to short days and a long growing season, and characterized by erect growth, rapid recovery after cutting, susceptibility to cold injury, bacterial wilt and leaf diseases. Representative strains occur in many warm, lucerne-growing countries: Egypt, west Asia, North Africa, India, Peru, and some Argentinean and Chilean strains.

Many local ecotypes exist throughout the traditional lucerne-growing areas, and these are often well adapted to local conditions and management practices. For example, much of the lucerne in the Near East is cut very low by sickle and often on a shorter cycle than is usual elsewhere. Unfortunately, local seed is usually expensive, scarce, dirty and of poor quality, with severe weed contamination. *Cuscuta* spp. (dodder; a parasitic plant) is a most serious weed and is a common contaminant in bazaar seed. Imported cultivars are not necessarily better than local landraces: Marble (FAO, 1989) presents data showing that local Near East varieties were as good as or better than imported varieties in a seventeen-cut trial in Saudi Arabia. A trial in Xinjiang-Altai of very cold-tolerant lucernes from other areas (mostly North America) showed very superior growth of the exotics during the establishment year, but all were dead next spring - only the local varieties survived the severe, snow-free winter. Although some countries in western Asia and North Africa have seed certification facilities, there is still a lot of room in the traditional areas for: (i) evaluation of local material; (ii) cleaning up the seed supply; and (iii) organizing marketing.

Since lucerne is grown in so many ways and places, installation methods vary and must be adapted to local realities. The remarks here are specific to crops for cutting. Lucerne can be included in semi-arid pastures, often at very low seed rates, but that is not our concern here. For hay production, land preparation should be thorough and deep. Where there is any possibility of hard pans or impermeable layers, especially for irrigated crops, sub-soiling or chisel-ploughing can be very beneficial. Seed should always be examined for the presence of dodder (*Cuscuta* spp.) seed if obtained from a non-certified source; samples containing even traces of dodder should be rejected. Rotation of lucerne with other crops is advisable; it should not be re-seeded immediately after ploughing out another lucerne crop, as, apart from the usual reasons of pest and disease control, there is a problem of autotoxicity which suppresses establishment (e.g., Jennings and Nelson, 1998) although the effect is usually short-lived and can probably be leached out by irrigation water.

Inoculation with the appropriate strain of *Rhizobium* is recommended on all newly-broken land, on fields which have not borne lucerne for several years and on all fields where the pH is less than 6.2. Suitable inoculants are widely available commercially. Lucerne seed of high quality is readily available on the world market. As noted above, however, there is often a scarcity of clean high-quality seed of locally adapted cultivars and landraces; a striking example is given in the Altai case study.

Lucerne is a cross-fertilized autotetraploid; its flowers must be tripped and cross-pollinated by bees if high seed yields are to be attained. Wild bees will trip lucerne, but it is advisable to place hives of honeybees near large seed fields to ensure pollination. Seed can be produced from fields close-planted for hay but, for specialized seed production, wider row-plantings usually give superior yields. In order to attain high seed yields it is essential that the plant has stored adequate energy in its roots; this is far easier to attain with spaced plants than in the dense swards desirable for hay or grazing, which are mown several times in a season. Row-planted lucerne gives better access to bees, light penetration and less humid conditions within the crop canopy. Row spacing depends on local conditions, with 90 cm a useful starting point. Seed rates should be low, 2 to 5 kg/ha, and thinning plants in the row may be beneficial. Weeding is very necessary in newly sown stands, to improve seedling survival and growth and to remove undesirable contaminants.

Seed stands should not be mown or grazed before first harvest, unless a cut is necessary for weed control. Established stands should be mown in spring prior to the development of the seed crop; depending on local conditions, several hay cuts may be taken before the seed crop, which must be so timed as to flower and ripen under favourable conditions. The seed crop may be cured and prepared for harvest by: (i) hand stripping, drying and threshing pods; (ii) mowing, windrowing, curing and threshing with a combine; or (iii) spraying with a desiccant, followed by direct combining of the dry standing crop. The last method is commonly used in intensive seed production, the first under small-scale farming conditions.

For irrigated lucerne, seed-bed preparation and land levelling must be done with the greatest care; any local variations in level which cause surface accumulations of water, even temporarily, predispose toward crown diseases. A firm, clean seedbed, free from large clods, is necessary, and tillage operations should be designed to this end. All perennial grasses and weeds must be destroyed before the crop is installed; *Cynodon dactylon* is a serious pest in warm climates. Fertilizer is essential and rates should be determined by local trial and experience; phosphorus (P) is the most important nutrient; sulphur (S) and potassium (K) may be locally important. Nitrogen is never required for properly nodulated lucerne and should not be used at any time. Occasionally, micronutrient deficiencies occur. Fertilizer should be applied immediately before sowing and worked into the top 1.5 cm of the soil. Where there is a serious P deficiency, a heavy basal dressing (80 - 100 kg/ha P) should be ploughed in.

The timing of sowing will have to be decided in the light of local conditions and experience; in areas with a rainy season, it may be possible to establish on rain and irrigate thereafter. High seed rates, 25 to 30 kg/ha are often used under flood irrigation, broadcast or close-drilled. Where small-scale farmers save seed of local ecotypes, excessively high rates, up to 80 kg/ha, are used, but this probably reflects the poor quality and low germination of that seed. Flood-irrigated fields should be watered a few days before sowing so that the seed germinates on residual moisture and only a light first irrigation need be given. On very light soils, however, it may be necessary to irrigate immediately after sowing. Under small-scale farming conditions, hand-drills worked by two people have proved very efficient and economical of seed. Where overhead irrigation is available, lower seed rates (15 to 20 kg/ha) are used. A seed depth of 0.5 to 1 cm should be aimed at; seed sown deeper than 2.5 cm will have very poor emergence. Where there is danger of high winds or sandstorms at emergence, it is advantageous to use a light seeding of a nurse crop (such as barley, oats or wheat), sown immediately before the lucerne, which is cross-drilled over it.

Weeds are a problem at establishment, except on some newly-broken land. They must be controlled early. On very small areas, weeding may be possible, otherwise control can be through cutting or herbicides. Cutting early is cheaper but less effective, and may weaken the stand; young plants should not be cut before there are two to four stems on each crown, but if they are being stifled by weeds an earlier mowing may be necessary. Pre-planting and selective herbicides are available and should be used according to the manufacturers' instructions.

For rainfed lucerne, again, a clean, fine and firm seed-bed is required. Seed rates are generally lower (5· to 10 kg/ha). Sowing must coincide with rainfall and autumn sowing must allow sufficient time for the plants to become well established before winter. The seed must be firmed in the soil, so drills with press-wheels are preferred. Broadcast seed should be rolled, with a ring-roller if possible. Fertilizer is necessary and rates should be judged by local conditions. In some cold areas with snow, lucerne can be established by sowing before snowfall, to germinate after the thaw.

Lucerne is the hay crop *par excellence* and has been so used since the beginning of its cultivation. However, as its growing points and growth habit differ from the more usual hay plants, which are grasses, and since multiple cuts are taken annually in all except the coldest parts of its range, care is required in both the timing and the height of cutting. The main source of loss is usually leaf shattering during handling and baling. Small-scale farm haymaking techniques often take this into account, employing methods such as rolling into small bundles after wilting and then drying, or drying at the homestead and sweeping up fallen leaves. For mechanized conditions, Frame, Charlton and Laidlaw (1998) quote the Pennsylvania State University Extension Service recommendations for minimizing forage loss and good conservation practice, as including:

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- mowing when there is little chance of rain, but be ready to take risks to avoid slippage of the cutting schedule;
- laying the cut herbage in as wide a swathe as possible to aid drying;
- "raking" at 60% DM, as slowly and as few times as possible; and
- baling at about 82% DM, so that the hay is not too dry, which would result in leaf-shatter during raking, or too wet, which would lead to high in-store losses.

As a general rule, lucerne should be mown at 25% - 50% flowering. After each cutting, lucerne, as a perennial, must recover and try to produce another crop; the energy for new shoot, leaf and feeder root production comes from carbohydrate stored in the root system until such time as the plant can once again photosynthesise sufficient energy for its needs. Root-reserve depletion continues until re-growth is 20 - 25 cm in height and the ground is almost fully covered by leaves. It is, therefore, of the utmost importance that the growth stage of the plant at mowing (and therefore the cutting frequency) be chosen to ensure both optimum re-growth and yield. This is related to elongation of basal crown shoots: at the 25% - 50% bloom (not 25% - 50% bud!) stage, 80% of the crowns should have basal shoots between 35 and 50 mm long for this to be a suitable cutting time. To ensure that the lucerne can compete with weeds, a full leaf canopy covering the whole soil surface must develop a few days after cutting; early cutting reduces plant vigour, encourages weed invasion, reduces yield and shortens the life of the stand. Leaving the crop after 50% flowering lowers the number of cuts possible and, hence, annual output; it will also reduce hay quality. Often in small-scale farming practice the field is not cut all at once, as some is cut daily to fit in with other tasks, so exact timing by growth stage is not always possible. In very cold areas, the last cutting should be sufficiently ahead of the first frosts to allow some re-growth to strengthen the root system; this can be grazed off once killed by frost.

Height of mowing

A stubble of 5 to 10 cm should be left to avoid damage to the young basal shoots, which provide the re-growth. This is not a problem with mechanized mowing, but hand-cutting, especially with a blunt sickle, is frequently done at ground level and causes considerable damage to growing points. Cutting height is an essential subject in small-scale-farming extension.

Maintenance and management

Lucerne does not tolerate continuous grazing for prolonged periods. In general, a five-week rest between grazings is optimal. Cutting regimes have been discussed above. Fertilizer application will depend on local soil conditions. Nitrogen is not required by correctly-nodulated stands, but phosphorus and potassium will probably have to be supplied annually to high-yielding, irrigated crops. A phosphorus content of below 0.18% for the whole top would indicate a probable response to applied P. A value of 1% K in the top indicates a need for K fertilizer. A dressing should be made late in the season, with 100 kg/ha of phosphorus and 300 - 500 kg/ha of potassium. Weed control may be necessary. Herbicides can be used for some weeds, while for mechanical cleaning and cultivation of established stands, narrow-pointed "lucerne tines," which pass between the crowns without uprooting them, can be used.

The dodders (*Cuscuta* spp.) are by far the most serious weed of lucerne. They may come in as seed contaminants, through irrigation water, dung from grazing stock, or by other mechanical means of transmission; stock fed on infested hay must not graze on lucerne fields. Once a field is infested, dodder seed will continue to germinate for many years. Seriously infested fields should be taken out of lucerne and cropped to cereals; clovers are alternate hosts. Dodders are parasitic and the seedlings must attach themself to a lucerne plant within 20 - 30 hours of germination. Some degree of control can be attained by hand-cutting affected patches, by using burners or contact herbicides like Paraquat (Gramoxone); the parasite and the lucerne stems should be destroyed to ground level. Treatment must be before the dodder has set seed.

Yellow lucerne

Medicago falcata

A cold and drought tolerant, creeping-rooted perennial, found over a wide range of harsh environments, including far into Siberia, Mongolia and the higher zones of the Himalayas, and as far south as North Africa. It is grown on a limited scale, but seed is difficult to harvest because of shattering pods. It is an important spontaneous fodder in many areas, including Nepal.

"Variegated" group of lucernes

This name is sometimes used for lucernes developed from hybrids *(M. sativa* subsp. *varia* (syn. *M. media*)) of *M. sativa* and *M. falcata,* and corresponds to the "variegated" group of lucernes. Cultivars such as Provence, Grimm and Ladak belong to this group.

Annual lucernes or "medics"

Several annual medicagos are important in the natural vegetation of the wheat-fallow rotations of the Mediterranean region, and some have been domesticated and widely sown in Australia, usually as self-re-seeding annuals in semi-extensive cereal-fallow-grazing systems. Most are suited to grazing, but some more erect species, such as *M. orbicularis* and *M. scutellata,* can be mown for hay.

SWEET CLOVERS

Melilotus spp.

Several species of *Melilotus* have long been cultivated for grazing, as fodders and as green manures. They are erect annuals or biennials, which smell strongly of coumarin (found in all parts of the plant), with a growth habit somewhat similar to lucerne, and trifoliate leaves with long leaflets. Poorly made hay or silage may be toxic to animals since a coumarin breakdown product causes internal bleeding. The seed of sweet clovers survives for years in the soil, so if a crop is allowed to seed before mowing or ploughing-in, sweet clover will come up as a weed for a long time.

The indigenous *Melilotus* spp. of North Africa have similar agronomic needs to medics (annual *Medicago* spp.) in wheat-fallow rotations, but *Melilotus* spp. seed more freely, are less palatable and have a lot of hard seed; sometimes they take over from and shade out medics and are difficult to eradicate. They can, of course, be left to grow tall and cut as hay.

Sweet clover is used in North America as fodder and green manure. It is also grown in northern China for soil improvement and fodder, as an over-wintering catch crop sown after wheat and harvested in spring, then ploughed in before a summer crop; it may be undersown in winter wheat.

It is widely used as a pioneer plant in re-claiming degraded grassland on the Loess Plateau; under such conditions the plants are often cut when mature and dried at the homestead. The coarse stems are valued as fuel and the finer parts used as fodder.

Three of the commonly grown sweet clovers have similar growing conditions and cultural needs, namely *M. alba, M. officinalis* and *M. suaveolens,* and are dealt with together. *M. indica*, a subtropical annual grown in India, is treated separately.

Sweet clover; Bokhara sweet clover; Daghestan clover

Melilotus alba; *M. officinalis*; *M. suaveolens*

Sweet clover (sometimes called white sweet clover) (*M. alba*) is a white-flowered biennial, but annual forms exist. Bokhara sweet clover (*M. officinalis*) is yellow-flowered. They originate in Europe and northern Asia, but are widely introduced and naturalized. Daghestan clover (*M. suaveolens*) is a biennial with some annual cultivars.

Growing conditions

The sweet clovers are suited to temperate climates and alkaline to neutral soils, but grow well at medium altitudes in the tropics. They can withstand very cold winters. *M. alba* and *M. officinalis* are widely sown in Canada and the USA. *M. suaveolens* is less widely used; in the USA it is grown in the north-central states. Sweet clovers can be grown in the high-altitude tropics; the annual Hubam cultivar of *M. alba* grew very well at Kitale, Kenya, as a cover crop and green manure. Sweet clover can re-grow from crowns with buds; to avoid it becoming a weed in the succeeding crop, it should only be ploughed in after the crown buds have developed into shoots.

Seed rate and establishment

Sweet clover is broadcast or close-drilled into a fine seed-bed at 10 - 15 kg/ha. Usually it nodulates freely, but lucerne inoculant should be used in new areas. The seed may benefit from scarification. Cvs Polara and Yukon are widely used in Canada, the latter for northern sites; cv Madrid is suited to warmer areas.

Hay

Spring-sown crops should have their first cut in late summer, giving adequate time for re-growth before winter. In the second year, two cuts are taken: the first should be cut high (25 cm), just before blooming, since old plants become woody and unpalatable.

Indian clover; senji

Melilotus indica

This yellow-flowered annual was previously an important *rabi* fodder crop in the irrigated tracts of northern India, but has been almost totally replaced by

Egyptian clover (berseem), and, to a lesser degree, shaftal, both of which are higher yielding and produce better fodder. It does, however, tolerate salt, hot conditions and drought much better than either of its replacements and still finds a place on marginal land. It is smaller and more bitter than the annual forms of *M. alba* and its palatability is moderate. It is usually broadcast and gives two or three cuttings of green fodder. Nowadays its value lies in its ability to produce some feed on land too poor or degraded for the better clovers, and for using or reclaiming saline land. Only local landraces are available.

CLOVERS

The genus *Trifolium* contains about 300 species; many are important in natural pasture and some twenty-five are cultivated. They are annual or perennial herbs and are among the most important fodders of temperate and Mediterranean climates. Some occur at high altitudes in the tropics, and most prefer rich soils.

Egyptian clover; berseem

Trifolium alexandrinum

Berseem is an erect, rather hairy, annual with a deep root system, and is trifoliate, with elongated, oblong leaflets. It is a very important cool-season fodder of the Mediterranean, western Asia, northern India and Pakistan. It is now grown in the USA and parts of Europe.

It is of ancient cultivation in Egypt, where it is a major winter crop, and from there was introduced to Sind in the early years of the twentieth century, where it proved so well-adapted to the conditions and farming systems of the irrigated tracts of the sub-continent that it spread rapidly throughout northern India (Roberts and Singh, 1951). It is now the major *rabi* season fodder, and cultivated on millions of hectares. This is probably the most rapid spread of a fodder species in recent times, and is all the more notable for being used mainly under small-scale farming conditions.

It is grown in the USA and, as a summer crop, in parts of southern Europe and at high altitudes in the Himalayan zone. Both single and multi-cut cultivars exist; the multi-cut Miscawi type is commonest. Egyptian clover has a high growing point and is not suited to grazing, but recovers well after mowing. Note that the name berseem is also used for other leguminous forages in Arabic speaking countries. Thus "berseem Hedjazi" is lucerne.

Figure 16. Training on farmers' fields - a good crop of berseem (Punjab, Pakistan)

Growing Conditions

It is a crop for areas with mild winters: while it withstands a light frost, growth is slowed or stopped by low temperatures. According to Fairbrother (1991), the usual limit in the USA is a winter temperature no colder than -6°C, apart from the cultivar Bigbee (Knight, 1985), which was selected from the Italian Sacramonte and will survive winters down to -15°C to -18°C. Bigbee is quick establishing and gives a good autumn cut if sown early. In southern Italy, it is grown as a rainfed winter crop. It will grow on a wide range of soils, preferring heavy loams, provided that they are not waterlogged. It is tolerant of relatively high salt concentrations.

Seed rate and establishment

In its main areas, berseem is sown in autumn, preferably early autumn, and establishes very rapidly; under irrigated conditions it gives four to seven or more cuts before flowering and dying off around May. Under irrigated conditions in Punjab, sowing is from late August to early November; the land is ploughed two or three times and planked to give a firm, level seedbed.

Phosphatic fertilizer should be incorporated at 125 kg/ha P_2O_5. An irrigation is given immediately prior to seeding with 20-25 kg/ha of seed. The seed is soaked overnight and sown broadcast (often mixed with sand to aid even distribution) into shallow standing water. Chicory (*Cichorium intybus*) is a very common contaminant of berseem seed and may be removed by flotation at the time of seed soaking. If a nurse crop is used, such as oats, then that should be drilled in before irrigating and sowing the berseem. Only light seed rates of oats (20-30 kg/ha) should be used. Sometimes sarson (*Brassica juncea)* is mixed with berseem to give bulk in the early cut, but, unless very low seed rates are used, it depresses clover growth and reduces the overall yield since it does not persist into the later cuts. Sarson is a favourite vegetable in the berseem-growing areas. Turnips are also mixed with berseem. Italian ryegrass has frequently proved excellent in trials, but seed supply is a problem for small-scale farmers.

Much berseem is grown from local landraces of the Mescawi type, but many improved cultivars are available, although seed production often lags behind research. In Pakistan, cvs Agaithi and Pachaiti are recommended. In Egypt, the recommended seed rates are higher than those used in India and Pakistan.

It can be sown into standing rice at the last irrigation but, unless the rice is very thin, only limited success is likely. Sometimes, when speed is more important than good husbandry, berseem is sown into rice stubble without further land preparation; yields are, of course, lower, but when the last sowing date is approaching this assures some spring feed with minimal labour input. In more northerly areas or higher altitudes, cool-season crops must be sown early.

Where the crop is traditional, seed is usually available in the markets, often contaminated with chicory, shaftal and melilotus. Farmers often sell seed they do not need, or want, themselves. Berseem seed is easy to clean and good commercial samples are usually available; Egypt is the main source in international trade. Recently, the quality and availability of berseem seed in India and Pakistan has improved markedly.

Berseem is a free seeder where climatic conditions are right. Cultivation for seed production purposes is as for fodder, and one or two cuts are usually taken; late mowing, however, reduces seed yield. Good, clean seed must be used for seed fields and the usual precautions taken to ensure purity and trueness to type. The crop is harvested by hand, with care being taken to avoid shattering, and then dried and threshed. From 800 to 1200 kg/ha of seed can be obtained.

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Maintenance and management

Ten to fifteen irrigations are required for fodder and about eighteen for seed production; very early sowings must be irrigated weekly at the initial stages, thereafter according to need. The first cut can be taken after fifty to sixty days if sown early in the season; the interval is greater in a late-sown crop. Cutting thereafter is at thirty- to forty-day intervals. The last cut will be in late April or early May.

Hay

The succulent stems are not easy to dry; hay is only made from the late spring growth when there is a peak of production, temperatures are high and the herbage is slightly drier. It is difficult to cure, and leaf drop is usually heavy once dried. Small-scale farmers often partially dry the crop in the field, then move it to house-roofs or other protected areas around the farmstead, and complete the drying there; the dropped leaves can then be swept up. In mechanized harvesting, a mower with a crimper speeds drying.

Crimson clover

Trifolium incarnatum

Crimson clover is an upright annual with striking, bright crimson conical flower heads. It is grown in southern Europe and the USA in the cool season for hay, often as a catch crop. It adapted to Mediterranean conditions and light soils, and is neither very cold tolerant nor drought resistant. Its seed has neither dormancy nor hard-seededness, and germinates immediately after ripening if in contact with moisture. It is easily made into hay in the hot season, when it is mown, but is hairy and not very palatable. Its cultivation is decreasing. It is drilled or broadcast, usually in autumn, at 15 - 20 kg/ha.

Red clover

Trifolium pratense

Red clover is a fodder of ancient cultivation. It is an erect perennial, originating in the temperate and sub-arctic regions of Eurasia. It has probably been cultivated since the fourth century, but its wider use began in the seventeenth century in Spain, Holland and northern Italy. In cool, favourable conditions, the plant may persist up to seven years, but it should generally be regarded as a two-year crop. It became very important in temperate agriculture in Europe and North America as a soil-improver within arable rotations in the eighteenth and nineteenth centuries, and is still an important hay crop. In UK, it has regained some of its popularity and is now used as a dominant component in swards for silage making.

In warmer climates it behaves as an annual or biennial. Because of its upright growth, and shoots developing from its crown, it is better suited to mowing than grazing. There are two main types and an intermediate one, with a multitude of cultivar types. The Common group are early, rapid-growing, short-lived and less winter hardy types. The Late or Single-cut are slower growing, hardy and more persistent. Single-cut types are more productive than Common under the temperature conditions and long days of high latitudes.

Growing conditions

It is cultivated in cool, humid, temperate regions, and withstands very cold winters. In North America, it competes with lucerne in the north, where the growing season is short. It has spread into subtropical regions at high altitude and under irrigation. A Chilean cultivar succeeded and seeded well at 1 800 m altitude in Kenya, grown as a one- or two-year crop.

Seed rate and establishment

Red clover is broadcast or drilled at shallow depth at 10 - 15 kg/ha into a firm seedbed. The seeds are small, so care must be taken in seed-bed preparation. In cool climates, it is generally spring sown under a cover-crop; in warmer climates, it is sown at the end of summer or the beginning of the wet season, usually in mixture with grasses, and perennial ryegrass is the commonest companion, although timothy and meadow fescue are also used, as a mixture of 4 - 5 kg/ha of grass seed and 10 - 15 kg/ha of clover seed. Spring sowing is preferred in areas of cold winters, since late sowing does not allow the seedlings to develop sufficiently to withstand the winter, and heavy losses can occur. Direct seeding is preferable to sowing under a cereal, since a laid crop will kill much of the clover. Seed is widely available and easily produced; the choice of cultivars, however, is often limited.

Hay

Red clover is an excellent and well-adapted hay crop, more easily handled when mixed with a little grass. Care must be taken to avoid leaf shattering, requiring careful turning and, in fast-drying conditions, by early putting into cocks or windrows.

Maintenance and management

Red clover is not suited to continuous defoliation, which rapidly leads to loss of stand. When not laid up for hay it should, therefore, be rotationally grazed or cut for silage.

White clover

Trifolium repens

White clover is a prostrate, creeping, white-flowered perennial with stems which root at the nodes. It is a pasture plant, mainly grown in association with grasses, but is used for hay. There are numerous cultivars, which can be divided into three main groups: the small-leafed wild types, which are more prostrate and suited to grazing, but low in yield and with very short stems; the medium-leafed or common group, which is intermediate; and the large-leafed Ladino types, which are tall, coarse and suited to haymaking.

Ladino clover is a general term used for the upright, large-leafed types of white clover, which are suitable for conservation. It is a spreading plant 40 - 50 cm tall, and almost a different crop from the small, grazing-type white clovers. It is as winter hardy as medium red clover, but less so than the small cultivars of *T. repens*. It is widely cultivated in North America, but rarely in pure stand except for seed production, since pure clover gives a dense swath which is difficult to aerate and dry, whilst mixture with a grass facilitates handling and drying. It associates well with tuft-forming grasses such as cocksfoot and timothy. USA cultivars include Regal, Sacramento and Lousiana. The Australian Haifa cultivar belongs to this group.

In northern Italy, it is usually cultivated as a three-year rotational crop (Piano and Pannicchiarico, 1995) and the landraces used do not persist well after the third year; mixture with timothy or cocksfoot is recommended. Espanso is an improved cultivar. Wild ecotypes closer in form to medium types are much more persistent than landraces.

Growing conditions

White clover is a plant of humid temperate conditions, and which grows in all temperate climates where there is adequate moisture and soils are fertile. It also grows well at altitude in the tropics and subtropics if moisture and soil fertility are adequate. In East Africa, the Louisiana types are best adapted. It is not a plant for very poor soils, nor for dry areas, and stops growing when hot dry weather sets in, but can revive rapidly when conditions improve.

Seed rate and establishment

White clover is usually grown in association with a grass, mostly in multipurpose swards which will be grazed as well as mown. It is added to seed mixtures at about 2 kg/ha. When sowing along with relatively large-seeded grasses (some of the ryegrasses, for example) it may be best to drill the grass and broadcast the legume over it, covering the seed by roller. Ladino is the main type grown for hay in the USA - usually in mixture with cocksfoot. White clover is very sensitive to competition at the establishment stage, so grass seed rate, early management and grazing must be designed to assure the strong establishment and growth of the clover seedlings.

Hay

White clover is usually a component of mixtures, not a pure-stand crop, so mowing time will usually be dictated by the overall mixture. Ladino should be cut at full bloom. It forms a dense swath, which requires early but careful turning; to minimize leaf-loss, the crop should be windrowed as early as conditions permit.

Maintenance and management

Clover cannot be maintained in mixtures which are only mown - the grass will shade it out fairly quickly, especially where nitrogenous top-dressings are used. Clover-based swards must, therefore, be grazed hard early in the season and, where necessary, top-dressed with phosphate, and possibly potash, to encourage the legume. Nitrogenous fertilizer must be avoided. The fields should be laid up for hay in late spring and early summer; the aftermath should be grazed.

Shaftal; Persian clover

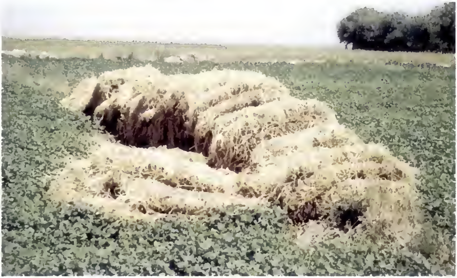
Trifolium resupinatum

An annual from central Asia, which is grown as a winter crop in western Asia. The cultivated forms are robust clovers up to 40 cm tall. Small, weedy forms are common in pasture and on rough ground in the Mediterranean zone through to Punjab. It was common in Punjab, but has lost ground to Egyptian clover in frost-free areas since the latter's introduction to the subcontinent early in the twentieth century, and is a common contaminant of berseem seed there. It is a very important hay crop in Afghanistan and similar Asian areas of cold winters. It is a minor hay crop in Australia and USA.

Growing Conditions

Shaftal is a plant of the Mediterranean and subtropical zones. It prefers neutral to alkaline soils and will withstand a fair degree of alkalinity, much more so than will *T. alexandrinum*. It thrives on heavy, moist soils and tolerates waterlogging; it commonly colonizes the wet patches in fields of Egyptian clover. It withstands hard frost, but generally is very slow-growing at low temperatures. In the higher parts of the western Himalayas and in Afghanistan, however, it is grown both as an overwintering annual and as a summer catch-crop. The young shoots are used as a green table vegetable in Pakistan and Afghanistan. In upland Afghanistan, it is grown, autumn-sown, to above 2 500 m altitude, where winter temperatures fall below -12°C; under such conditions the plant is dormant, and snow-covered for months, but grows rapidly when temperatures rise in spring. In the larger part of its range it is cultivated as a winter annual, sown in autumn but producing little before spring.

Figure 17. Shaftal, with trusses drying on a bund (Herat Afghanistan)



Seed rate and establishment

Irrigated shaftal is established in the same way as berseem, but at a lower seed rate of 5 - 10 kg/ha. In its traditional areas, most is from locally-grown seed which has had little or no quality control, and in some places farmers use much higher seed rates. Seed quality should not be difficult to improve, as it is a free seeder. Landraces in Afghanistan, especially in Ghazni and Herat Provinces, where shaftal is a very important hay plant, are much superior to ordinary Pakistan material. Improved tall-growing cultivars are available internationally, such as cv Maral.

Sowing into another crop

Shaftal may be broadcast into standing rice at the time of the last irrigation. This can give a reasonable stand for minimal effort if the crop is a thin one with poor ground cover (as is often the case with basmati cultivars). In any well-grown crop, however, the clover seedlings are likely to be shaded out and the resulting crop is often late and poor. As a summer catch crop on high altitude sites in Afghanistan, it is sown in ripening wheat in late spring.

Hay

Shaftal makes good hay and is easy to cure, although the usual care must be taken to avoid leaf-loss. Traditional practice in parts of Afghanistan is to tie the crop into small trusses as soon as it is wilted, dry those first on the bunds, turning from time to time, and then in loose stacks before final storage. In this way, most of the leaves are retained within the trusses.

Vetches

Vicia spp.

Several species of *Vicia* are grown as fodders, in areas of mild climate, often mixed with oats or other cereals. Most are rambling vines climbing by tendrils; the commonest are: common vetch (*V. sativa*), and woolypod, winter or hairy vetch (*V. villosa* subsp. *varia* (syn. *dasycarpa*)). Others of lesser importance include purple vetch (*V. benghalensis* (syn. *atropurpurea*)); bitter vetch (*V. ervilia*); Hungarian vetch (*V. pannonica*); and narrow-leaved or blackpod vetch (*V. angustifolia*).

Growing conditions

Vetches are cool-climate crops that tolerate soil acidity and gravelly soils. They are grown as summer crops in temperate zones, and some are grown as winter crops in the Mediterranean and subtropics, especially *V. benghalensis* (syn. *atropurpurea*) and *V. sativa*.

Cultivation

In cool climates, vetches are usually sown mixed with cereals (oats or wheat), for hay or silage. Cultivars should be chosen so that the two crops mature at the same time. Seed rates vary greatly with species and cultivar, but 20 - 30 kg/ha of vetch is common, with twice as much of oats. Vetches seed heavily and on-farm harvest is simple, as it is a self-fertilized crop; seed crops may be grown with a cereal for support.

Harvesting as hay

Pure stands of vetch and mixtures should be mown when the lower vetch pods begin to fill. Again, it is important that the maturity of the vetch and its companion plant be synchronized. Vetch may tangle round the swathe board, so care must be taken in setting and using the mower.

OTHER LEGUMES

North China milk vetch

Astragalus adsurgens

A tall, hardy, robust long-lived perennial, which may attain 1.5 m in height, with a deep tap root. It occurs wild from central China to Mongolia. Cultivated types originate from central Chinese material. It has been widely used in pasture renovation, watershed management and fodder development in the Loess Plateau area. Its palatability is only moderate, and it is better accepted as silage or hay than in the fresh state. North China milk vetch withstands very cold winters, but requires a hot growing season. It prefers well-drained soils of high pH and survives on low rainfall, from 300 mm/yr, but uses a great deal of the available moisture. The common cultivars are very late flowering and their range in cold, northerly areas is limited by difficulties of seed production; they flower towards late summer, which is often too late for seed set if they are cut by frost. The crop may, of course, be grown for fodder in areas with too short a growing season for good seed-set. It grows wild as far north as the Mongolian Republic, so ecotypes adapted to shorter growing seasons must exist.

Seed rate and establis

It is line sown at the o the rains at about 5 kg/ha of scarified seed, but may be broadcast. It is sually harvested in the first year in semi-arid areas. Seed production is by cutting the whole plant once the seeds are fully formed, drying and threshing; seed growing areas must fit the flowering pattern of the cultivar.

Hay

The plants are usually cut once annually, at early flowering, then partially dried in the field and finally cured at the homestead. As with sweet clover in fuel-scarce areas, the stems may be used as fuel and the finer portions reserved for feed.

Maintenance and management

Mowing and perhaps weeding is all the crop usually receives once established, but top dressing with phosphatic fertilizer would improve its longevity and production.

Chinese milk vetch

Astragalus sinaicus

A short-lived shrub which is widely grown in central and south China as a winter crop on rice fields which are not sufficiently well drained to allow the growing of wheat. Unlike many milk vetches, it is non-toxic and palatable, and well grazed by both large ruminants and swine.

Growing Conditions

It thrives in areas of mild winters, but will withstand light frost. It is tolerant of temporary waterlogging.

Cultivation

It is broadcast when the rice is harvested in autumn and grows luxuriantly in spring. The crop is cut in early spring, when other green feed is scarce. Immediately preceding ploughing, when the milk-vetch is usually in flower, it is grazed and some may be mown and dried. The remainder is ploughed under as green manure. It is a free seeder, and farmers save seed from reserved parts of green-manure fields.

Crown vetch

Coronilla varia

A creeping, rhizomatous perennial, 30 - 50 cm tall with showy flowers, widely used in southern Europe as cover on road cuttings and other banks in need of protection. It is of European origin and is grown in the USA. Crown vetch's palatability is only moderate and it is very aggressive, so it tends to choke out associated plants in grazed mixtures. It is difficult to extirpate once established and will often re-establish after ploughing out.

Growing conditions

Crown vetch is a plant of neutral to alkaline soils. It prefers warm summers but withstands cold winters. It is drought tolerant and will grow with under 500 mm annual rainfall. In northern Asia it has shown promise in experimental plantings on the Loess Plateau, and was the only really successful fodder seen in the Lhasa River Valley, at between 3 800 and 4 000 m altitude.

Cultivation

Seed must be hulled and scarified, and, in new areas, inoculated with a specific inoculant. Drill or broadcast at 5 - 10 kg/ha on a well-prepared seedbed in spring.

Harvesting as hay

The stems are coarse so conditioning would be useful. Under small-scale farming conditions, field wilting, followed by tripod or homestead drying, could be tried.

Sulla

Hedysarum coronarium

Sulla is a biennial, or short-lived perennial, herb with a deep rooting system. The cultivars grown for hay are erect, coarse, and grow to 1.5 m in height. The pods, which are lomented, almost thorny, and indehiscent, break into sections on harvest. It is important in southern Italy, Greece, southern Spain and North Africa. Prostrate ecotypes suited to grazing exist in the wild. Those cultivars of which seed is usually available are best suited to mowing, but can be grazed in winter and early spring (Kernick, 1978).

Growing Conditions

It is a plant of Mediterranean climates with mild winters, and will only tolerate light frost. It occurs naturally on deep, calcareous clays, but can be grown on a wide range of soils provided that they are alkaline, contain adequate lime and if the seeds are inoculated at the time of sowing. It is drought resistant and can be grown under rainfalls down to 500 mm/yr.

Seed rate and establishment

For hay it must be grown closely spaced, with an even stand, otherwise the stems will be too coarse for easy drying (the stems can be over 1 cm in diameter). A fine, compact seedbed is necessary and the sowing must be shallow. Hulled seed can be very shallowly drilled at 10 - 20 kg/ha; unhulled seed is usually broadcast at 30 - 50 kg of pods per hectare. Pods must be barely covered. Sowing is in autumn, but must be early enough to allow the plants to establish before temperatures become too low. In the Tunisian Tell, sulla should be sown before the end of October. When hot dry weather has prevailed at harvest (which is usual), there is a high proportion of hard seeds; scarification may be necessary. Hulled seed usually germinates evenly, whereas unhulled does not; the former is best for establishing hay fields; the latter is only suited to pasture improvement. Sulla for hay is sown in pure stand since its lush, tall growth from mid spring tends to choke out other forages in mixtures.

Harvesting as hay

Sulla grows slowly in winter but develops very rapidly in spring, with a peak of production from late March into May. It is usually dormant through the heat of summer. Several cuts may be taken in the second year. It may be grazed in winter and early spring when green feed is scarce, then set aside for hay. Martinello and Ciola (1996) state that, in Italy, sulla and sainfoin are usually grazed during October to April, and made into hay in May-June.

Maintenance and management

Sulla is a two-year crop and given little treatment other than grazing or mowing once established and any early weed control completed.

Sainfoin

Onobrychis viciifolia

An erect, long-lived perennial growing to 50 - 75 cm, with a deep tap root and erect, hollow stems arising from basal buds on a branched crown. It originated in central and southern Europe and temperate Asia. Its indehiscent pods contain a single seed. It can be used for hay and withstands grazing better than does lucerne.

There are two types: common and giant. The latter gives more luxuriant growth but does not persist, and is used for two-year hay crops; common may persist for four to eight years. It does not cause bloat due to the presence of concentrated tannins in the leaves.

Growing conditions

Sainfoin is not as high-yielding or as excellent a fodder as lucerne, but withstands drier conditions and poorer soil. Therefore, when used in the same area as lucerne, sainfoin is sown on sites where lucerne would not persist. It is adapted to dry, calcareous soils with a pH of 6 or higher under temperate conditions, and will withstand cold winters. It can grow with 300 mm annual precipitation and over, but must have good drainage. It is cultivated in central Europe, Turkey and the central Asian highlands, Kyrghyzstan, and Tadjikistan, and some Mediterranean countries, as well as North America. It has been tried on a field scale, successfully, in the Loess Plateau area of NW China. In Turkey and central Asia, it is traditional and popular.

Seed rate and establishment

Unhulled sainfoin contains a high proportion of hard seed. For hulled seed, rates of 20 - 30 kg/ha broadcast or close-drilled are used, with up to 100 kg/ha for unhulled seed. Eski is a cultivar developed from Turkish material; Melrose is Canadian; Zeus and Vala are Italian cultivars.

Hay

As for lucerne, but often only one cut is taken since the crop is on the poorer soils. The aftermath may be grazed lightly, but it is safer to rest the plants in late autumn and graze the aftermath once growth has ceased.

Serradella

Ornithopus sativus and *O. compressus*

Serradella is the common name for two annual forage legumes from southwest Europe. *O. sativus*, pink serradella, is an erect, cultivated plant with no wild counterparts. *O. compressus*, yellow serradella, is widespread in natural grazing around the Mediterranean. They are semi-erect plants with pinnate leaves, which reach up to 50 cm in height. Their segmented seed pods break, on maturity, into segments, each containing a seed. Germination of unhulled seed is often low and erratic; they are hulled mechanically.

Growing conditions

Both serradellas are grown as cool-season annuals in areas of mild winters and are well adapted to sandy soils. Outside its native area, serradella is grown in the winter rainfall zone of Cape Province and as a minor crop in Australia. It showed promise at high altitudes in Kenya in the 1950s, but was not adopted into farming systems.

Seed rate and establishment

Seed rates vary widely, from 5 to 15-20 kg/ha, as hard-seededness is common.

Inoculation of seed on land where the crop has not previously been grown is recommended, but is unnecessary where serradella or lupins have been grown in the past. Lloveras and Iglesias (1998) state that pink serradella is grown on the Atlantic coast of Spain in double cropping systems with maize, or in multi-level cropping with grapes. The cv Carnota is mentioned and the seed rate used was 50 kg/ha of pure germinating seed.

Hay

It is mown in the usual way, with precautions against leaf-loss. In the Mediterranean basin, haymaking is usually from the peak of spring growth to early summer.

PULSE CROPS FOR HAY

Some pulses are grown for hay. The haulms of many are good fodder, if they can be conserved. They are not, however, nearly as important fodder as the cereals.

Common groundnut; peanut

Arachis hypogaea

Groundnuts are rarely specifically grown as a forage but, properly handled in suitable climates, the haulms can be made into a high-quality fodder equivalent to good hay. Their harvesting is described in Chapter IX.

Growing conditions

It is a warm-season crop that is killed by frost. Dry weather is essential for ripening and harvesting. Well-drained light, fertile soils are suitable; it will grow on heavier soils but harvesting on them is difficult. The crop cannot tolerate waterlogging. Commercial cultivation is usually in areas with about 1 000 mm annual rainfall, half of which should fall during growth.

Cultivation

It is usually grown as a row crop. Cultural practices which favour nut production also favour forage.

Guar; clusterbean

Cyamopsis tetragonaloba

Guar or clusterbean is a strong-growing bushy annual, 1 - 3 m tall, with erect linear pods in clusters. It is traditionally grown in India and Pakistan as a vegetable, fodder and green manure crop. Its seeds are the source of a gum which has industrial and agro-industrial uses, and guar is now grown as an industrial crop in India and several countries with hot growing seasons, especially the USA.

Growing conditions

It is a crop of the drier tropics and subtropics, and requires a hot growing season. It is very drought resistant and grows best on light soils. Some fodder cultivars have been developed in India.

Cultivation

In pure stand for fodder, the crop is broadcast at 30 kg/ha or drilled in close rows at a slightly lower seed rate. It takes about 15 weeks to come into pod. It is usually mixed with sorghum as a fodder on light soils under dry conditions. In India, it is often irrigated, and for fodder is often mixed with sorghum.

Hay

Guar and mixtures with sorghum, are made into hay, although care has to be taken in assuring that the stems dry through without incurring too much leaf loss, so windrowing or tripod drying is probably best.

Soybean

Glycine max

Soybean or soya has been grown for hay in the USA and some subtropical regions, but needs a lot of labour and is out of fashion.

Growing conditions

Soybean grows over a wide range of climatic conditions, provided that they have a hot growing season which is not too humid and that the soil is fertile and well drained.

Cultivation

Cultivar choice is very important, since it is a short-day plant and cultivars have a short range of photoperiod tolerance. Cultivars for hay are later maturing than those grown for hay. Sow thickly so that stems are not too coarse. It is usually row-cropped, seeded at 30 - 50 kg/ha, but can be mixed with Sudan grass for forage or hay.

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Harvesting as hay

Mow when the beans are well developed and lower leaves yellowing - but earlier if weather so indicates. Cure in cocks if possible, or dry on tripods.

Field pea

Pisum sativum

Field pea is an ancient and important crop, widely grown in temperate conditions as a vegetable and dried pulse. It is sometimes grown in mixture with oats or another small-grain cereal. The haulms of peas grown for fresh use or conservation are a valuable fodder if conserved at the time of harvest.

Growing Conditions

Peas need a cool and relatively humid growing season and fertile soils. They can be grown in the high-altitude tropics and as a winter crop in the subtropics, but their best growth is as a summer crop under temperate conditions.

Cultivation

A little is grown as fodder, usually mixed with oats. Pea haulms, available on a large scale from industrial crops for freezing and canning, as well as the fresh crop and pease straw are very useful by-products. Oat-pea mixtures were used to support peas grown for their grain but, with the development of modern pea cultivars that are much less affected by lodging, such mixtures have greatly decreased in importance. For hay, with or without a cereal, cut when the pods are filled, but well before ripening, as leaf-fall can occur at that stage.

Fenugreek

Trigonella foenum-graecum

Fenugreek is a highly aromatic annual used as a pot-herb, spice and fodder. It is widely grown in India and neighbouring countries as a flavouring and fodder, and in North Africa and western Asia as a fodder and spice.

Growing conditions

It is grown as a cool-season crop in India and the Mediterranean region, both irrigated and as a rainfed crop. It will grow on a wide range of well-drained soils.

Cultivation

It is broadcast or drilled at 20 - 30 kg/ha in pure stand, or mixed with oats.

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Mixtures with small-grain cereals are best for haymaking. It should be mown when the pods are well formed. The hay is nutritious, but highly aromatic and may flavour milk.

Cowpea

Vigna unguiculata

Cowpea is a common bushy, trailing or climbing annual pulse of the tropics, subtropics and regions with hot summers. It originated in Africa, with a large number of types and cultivars. It is widely cultivated as a pulse and a green vegetable, and on a lesser scale as a fodder. It is grown for hay in South Africa and the USA.

Growing conditions

It requires a hot growing season and good drainage, but tolerates poor, acid soils. On the equator, it can be cultivated up to about 1 500 m altitude. Cowpea can grow under low rainfall conditions and will give some crop on 300 mm.

Cultivation

Choice of cultivar is very important, as cowpeas are sensitive to photoperiod. They are usually row-cropped and may be mixed with maize, sorghum or similar for green forage.

Harvesting as hay

Cowpea should be cut at the green pod stage, but is not easy to dry; traditional methods involve tripods and a lot of labour. Cowpea can also be cured in long, narrow cocks after windrowing.

CHAPTER VII

HAY FROM NATURAL PASTURE

This is the original source of hay, and is still common in parts of Asia and Europe. It is decreasing in large-scale commercial farming since better hay can usually be made more cheaply from sown crops, but it is still popular with subtropical and temperate small-scale farmers. Hay has yet to catch on with small-scale farmers in the tropics, probably because of the absence of a winter and the very poor quality of mature tropical grass.

"Natural" pasture takes many forms, all of which have in common only that the herbage has not been sown. It is usually on land unsuited to arable cropping for some reason: because of stoniness, seasonal waterlogging, slope or a short growing season, or due to pattern of rainfall distribution or temperature. Most is grazed, but some is used for hay, which is made on sites as different as meadows, almost sheer clearings on hillsides, subtropical forest land closed for regeneration, alpine grassland, steppes, or a host of other uncultivated lands. Natural hay is mainly from grasses and herbs, but in a few cases shrubs are mown and dried. Hayfields may be private or under common ownership, the latter often with customary rights. Several traditional systems of hay production are described in the case studies, including vast areas of forest land closed for regeneration or protection in India, where grazing is forbidden but grass-cutting allowed; the steep clearings of sub-Himalayan mountains; meadows in Turkey; the steppes of Mongolia (where cooperative stock-rearing has recently been replaced by private); the Sahel; and the Ethiopian highlands.

Various degrees of human interference or "improvement" have usually been applied to natural grassland, and more especially to the areas to be mown for hay. Fire is a potent grassland management tool, especially for the control of woody species and the removal of senescent herbage. Introduction of animals, domesticated or wild, has a great effect on vegetation. Manipulation of grazing pressure and control of grazing leads to changes in botanical composition without deliberate introduction of species. Bush-clearing, fencing, drainage, application of fertilizers and trace elements are more intensive interventions in modifying natural vegetation as pasture. Introduction of grasses and legumes, without much cultivation, is yet a further stage in modification. Many good natural grasslands have been replaced by arable while, in some countries, marginal agricultural land has been allowed to revert to "natural" grassland as the profitability of crop production declines. Self-sown, grazed, fallows are important in some systems.

CHOICE OF LAND FOR HAYMAKING

The better pasture is usually reserved for hay, but many factors must be taken into account, in addition to good growth and suitable botanical composition of the pasture.

- ***Title to the use*** of hay land is essential; in some communities there are traditional hay lands and local customary practice for their use.
- ***Protection from stock*** during the growing season must be possible; in other than fenced areas, this would require the agreement of all users of the surrounding grazing lands.
- ***Topography and land surface*** must be suitable for the method of harvest and transport to be used.
- ***Accessibility for transport,*** as, although hay may be carted by many methods, including porterage in mountain areas, the fields must be easily reached by the mode of transport which is used locally.
- Areas infested with ***toxic plants*** that retain their toxicity once dried must be avoided. Often, such plants are not grazed by stock but will be eaten once cut and wilted or made into hay. Grasses with a high cyanoglucoside content are safe once dried, but plants such as goat's-rue (*Galega officinalis*) or ragwort (*Senecio jacobaea*) are a serious pasture weed in western Europe and parts of North America. Loco weed (*Astragalus* spp.) remains toxic when dried. For example, Faliu, Puyt and Jean-Blain (1985), discussing *Galega officinalis* poisoning from hay in southern France, stated that there is little danger from young plants, but if gathered when the plant is flowering or fruiting, the hay is dangerous if it contains over 10% *Galega*. Dickinson and King (1978) found appreciable quantities of alkaloid in air-dried ragwort.

Toxicity is not limited to the higher plants: mycotoxins occur in several forages. Some of the more important toxin-producing fungi in forages are *Claviceps* spp., which form sclerotia (ergot) in grass seed-heads, and *Acremonium* spp., which are endophytes (Towers and Seigel, 1993). Both produce ergot alkaloids. *Claviceps* spp. occur worldwide: *C. purpurea* infects hundreds of C3 grasses, and *C. paspali* occurs in nineteen *Paspalum* spp. Danger from ergot can be avoided by mowing before the seed-heads are formed. *Acremonium* endophytes are maternally inherited components of a grass-fungus symbiotic association; they are widely reported in *Festuca arundinacea* and *Lolium perenne.* Control is by replacing the crop with endophyte-free material.

COMMUNALLY MANAGED HAY-LANDS

These present problems of management, especially where strong, traditional systems are lacking or have broken down. It is essential that mowing and grazing rights on specific areas are defined by traditional or legal means. This is the case in most places where haymaking from natural pasture is traditional, but where the system has been interrupted (see the case study on Mongolia) difficulties can arise. If rights are not defined, there is no incentive to maintenance if anyone may mow.

Usually, in addition to defining mowing rights and dates of closure to livestock, the seasons when grazing are forbidden are also defined and fields may be open to communal grazing in the off season. If enclosure takes place, then real improvement of the herbage is possible. Similar situations existed in many parts of Europe before land titles were developed and farming modernized (see Fenton, 1980).

THE QUALITY PROBLEM OF TROPICAL GRASSES

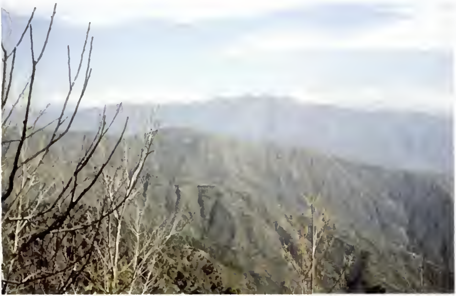
In the tropics, the quality of stand-over feed (and hay from mature material) is not at all the same as at higher latitudes or in semi-arid areas where stock can often overwinter on dried-off feed. 't Mannetje (1981) states that

> "Tropical pastures do not meet the nutritional requirements of ruminants for maximum production. The main limitations are availability of green feed for at least half of the year in seasonally dry regions, and low nutritive value during most of the season of active growth."

Butterworth (1985) points out that the greatest limit on intake of green forage in the tropics is often the restricted amount on offer, including presence of material which is unpalatable because of senescence. The season of scarcity in the tropics is governed by rainfall, not temperature; the length of the dry season varies with latitude and site, from a few months to over half the year, but even when there is adequate moisture late in the season, especially in high-rainfall areas, the mature herbage may be almost worthless as animal feed and only selective grazing, and fire to "freshen" the grass, may assure survival of the stock. Hay made from natural grassland in the tropics is, unfortunately, much less likely to give satisfactory results than that from other zones; bush hay is usually made late in the rains because of the difficulty of drying at other times and is no better than straw or stover. This, along with a relatively low stock density in the past, may be why there is little if any tradition of haymaking in the humid and sub-humid tropics. Hay from sown crops can be made on mechanized farms under tropical conditions, but its quality will be governed by the genetic limits of tropical grasses, except at high altitudes, where exotics can be grown.

Discussing herbage quality from tropical pastures - at all stages, not just over-mature - Butterworth (1967; 1985) indicates that the crude protein content of 235 samples was 7.5% ± 3.5%, with 235 under 7% (7% is the level for zero liveweight gain). Crude protein content decreases with maturity as the cell contents are diluted by structural components. As the crude protein content decreases, so does its digestibility. Of 473 samples, 58% were below the needs for growth of beef cattle. The average total digestible nutrients (TDN) of 312 samples was 54.0 ± 7.9%, with 43.5% below the 55% level recommended by the Agricultural Research Council (ARC) for grazing cattle; in tropical pastures, TDN is less likely to be limiting than is crude protein.

Figure 18. Precipitous hay land in Uttar Pradesh, India; the slopes in the middle distance are hand-mown for hay



TYPES OF NATURAL HAY

Hay in the monsoon zone

Haymaking is traditional and widespread in the hills of northern India, Nepal and Pakistan. In the monsoonal lower hills, hay is made from communal grazing which is closed to livestock for several months, from before the monsoon and through it. Sometimes the stock are moved to high-altitude pastures. These hay lands belong to the community, but family rights to cutting are often recognized; the seasons of closure are agreed at village level. Hay is also made from areas of forest closed to grazing but where cutting and carrying off of grass is allowed by permit; the cutting season is determined by the forest authorities. During the monsoon, the weather makes haymaking difficult so the herbage is usually not mown until after the rains, by which time it is coarse, overripe and of low nutritive value. It is in these areas of chronic feed scarcity that hay is highly prized as a winter feed. The hay consists almost entirely of tropical grass genera, such as *Heteropogon, Chrysopogon, Bothriochloa* and *Arundinella,* which mature and lignify quickly. These "hayfields" are often steep to precipitous clearings, and all operations - mowing, turning, bundling and transport - can only be done by hand. The "management" of these hay fields is limited to decisions on closure periods (they are usually grazed after harvest and through the winter) and occasionally removal of invading shrubs, such as *Dodonea viscosa.* The hay produced in the hills is almost entirely for local use. In the drier parts of peninsular India, large amounts of hay are made from closed forests, but this is largely a commercial operation to supply the peri-urban dairies of the great cities, especially Bombay, so mechanized cutting and baling for transport are used.

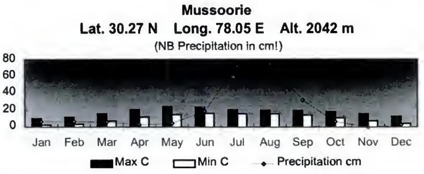


Figure 19. Monthly precipitation and temperatures in Musoorie, India.

Figure 20. Natural herbage drying, spread out and then heaped ready for transport to the homestead (Mehterlam, Afghanistan)

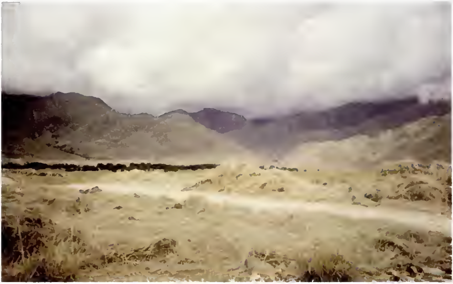
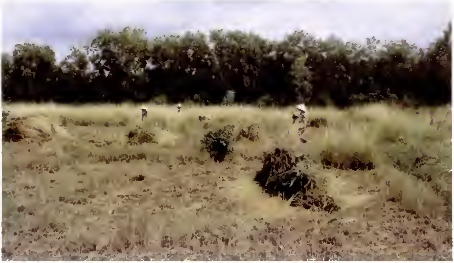


Figure 21. Mowing over-ripe grass by sickle, after the main rains (Viet Nam)



Hay in the steppe

Mongolian winters are long and hard, and the growing season is less than 100 days for most of the country. The economy is almost entirely pastoral, so some hay is essential to help see weak stock through to spring, and also for the horses on which the herders depend for their work. For a long time, the livestock industry was organized into a small number of very large grazing cooperatives.

Crop and fodder production is limited by climate, although a little oat hay was made in favoured sites during the cooperative era. Most of the hay is made from natural pasture, with some 20 000 km2 being mown annually in the early 1990s by mechanized cooperative teams. The bulk of the hay land is in the north, and cooperatives bought mowing rights there. Hay was transported over vast distances at subsidized rates, especially for emergencies. Yields were stated to be a little over 1 t/ha of made hay. Management was mainly limited to land clearing and, sometimes, rotation of cutting date. Repeated mowing of the same land led to a gradual decrease in yields; fertilizer responses could be impressive if the rain fell at the right time, but was totally uneconomic. With the decollectivization of the livestock industry into traditional units of small family groups, mechanized haymaking has disappeared, as has transport over large distances. Hay is now made locally, where herbage quality and availability allow, mainly by manual methods, but also with some horse-drawn equipment. Although herders have title to grazing land, title to hay land is still being organized, so management is chaotic. No improvement is likely until groups have long- or medium-term mowing rights.

Hay from tropical pasture

The cause of low animal productivity on tropical grasslands is mainly nutritional, because of poor seasonal distribution and low feeding quality of fresh herbage. Both quality and quantity are influenced by the stage and season of growth, climatic conditions and soils, as well as by the genotype of the forage itself. Mature tropical grass is highly lignified and its feeding quality may be even poorer than that of crop stovers; this may be one reason why hay-making is not traditional with most tropical pastoral peoples.

The case study on hay in the Sahel describes extension work on conservation of natural herbage in a climate with a very long dry season and a short and light rainy period. Maradi (Figure 22) is a typical station. Humidity is usually low and there is usually enough sunshine to allow mowing and drying in one day. Many tropical and subtropical sites (such as Musoorie; see Figure 19) do not have good drying conditions, so haymaking during the rainy season is not possible.

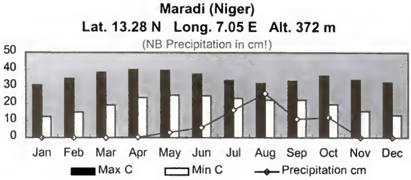


Figure 22. Monthly precipitation and temperature in Maradi, Niger

NATURAL HAY IN TEMPERATE AREAS

Meadow hay

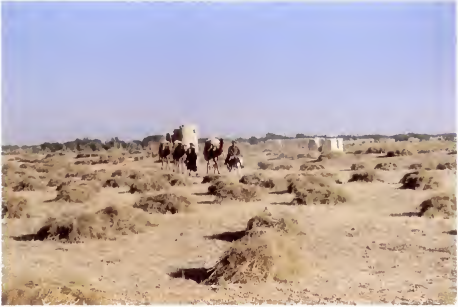
In temperate and montane regions, natural hay is often made in low-lying, seasonally waterlogged, meadows. Although they produce a flush of herbage tall and dense enough to be mown (often containing rushes (*Juncus* spp.), broad-leaved plants and other bog vegetation), they are unsuitable for cropping. Until the development of sown fodder within a crop rotation, which was the key to intensification of both livestock and arable farming, this was the little hay which was made in western Europe. The quality of hay from such meadows is often mediocre. The studies from Altai (China), Mongolia and Turkey mention meadow hay. Smith and Crampton (1914), in their classic report on British grassland, when discussing meadows stated that the soils are generally porous loams with a high water table and usually subject to periodic flooding.

Meadows require greater summer warmth, and here are found in lowlands or in sheltered places such as riversides and estuaries. This would be an extensive group if soil and topographies were not so much used as arable land. Meadows occur at high elevations in Alpine conditions, with a permanent snow-line but warmer continental summers; under these conditions, the spring flushing of the slopes is widespread and growth rapid. The turbid water from melting glaciers is highly valued in the Swiss Alps and used to irrigate high pastures in many parts.

HAY FROM SHRUBS

Trees and shrubs are important dry-season sources of feed, especially good quality forage, during the dry season in warm climates, and in winter in some cold climates. For the most part, they are wild or semi-wild, protected plants which are lopped, bowed or their pods are licked from the ground. Some trees are, however, used in the dried form; either their dry twigs and leaves are used (*Alhagi* in northern Afghanistan (Figure 23); *Ziziphus* spp. in the semi-arid subtropics; *Leucaena* and pigeonpea (*Cajanus cajan*)) or their pods are used. Although many trees are referred to as "multipurpose," it is the species which is multipurpose, not the individual trees, which must be managed for whatever main product is most desired, be it fodder, timber, fruit or firewood. The fruits of several leguminous trees are dried and used as feed, either from cultivated plantations or semi-domesticated stands. Though not exactly hay, they are dried plant products and should be borne in mind for areas where they are adapted. Pods provide a concentrate feed but may require treatment and grinding before use, since some have anti-nutritional factors, and also much of the feeding value is in the seed, which, unless treated, passes undigested through the digestive tract of the ruminant. The pods of the carob or locust (*Ceratonia siliqua*) of the Mediterranean region have been used since antiquity for both human and animal food, and are sold internationally; the tree fruits in southern Africa but has not developed there as a feed source (Topps and Oliver, 1993). The apple-ring acacia (*Faidherbia* (syn. *Acacia*) *albida*), which is widespread in the low-altitude semi-arid areas of Africa, produces large spiral pods which are prized as livestock feed. Some trees are planted, but the most are wild, but protected. The pods are harvested either for domestic use or sold as concentrate feed in local markets.

Figure 23. Hay from camelthorn (*Alhagi* sp.) drying (near Balkh, Afghanistan). A rare instance of hay being made from a shrub.



The seed pods of the algaroba - a tropical American leguminous tree - (*Prosopis juliflora*) are an excellent feed for ruminants and monogastric stock once properly processed. It is a very hardy and versatile tree adapted to areas of unreliable and low rainfall, and which can produce on saline soils and utilize low-quality irrigation water. It is a plant of warm climates and withstands only light frosts. Algaroba is a multipurpose species which produces timber, firewood and honey, as well as edible pods. For pod production, it must be cultivated expressly for that purpose, in spaced rows to allow full flower production. The foliage is unpalatable, so the under-storey of established stands can be grazed, but stock should be excluded during pod production.

Algaroba is widely used in its native region and is being developed industrially in northeastern Brazil, where small-scale farming production is combined with centralized processing. (Habit and Saavedra, 1988; Riveros, 1992). The tree has been widely introduced, naturalized and planted for firewood and soil conservation throughout the drier tropics and subtropics, but is rarely managed as a pod-producer; bush encroachment and small weedy trees, coppiced very young, are a common sight. Leaves which have dropped naturally because of senescence are very poor in nutrients.

Elsewhere, in some areas of serious feed scarcity, especially northern Pakistan and parts of the mountainous areas of Afghanistan, leaves from fruit and multipurpose trees, notably apricot and mulberry, are carefully collected and made into "hay" for winter use.

MANAGEMENT OF NATURAL HAY LANDS

Land preparation

Where hay-making is traditional, the hay lands are often meadows, although there are also very steep mountain hay fields, which have usually been gradually cleared over a long time. It is essential that any land to be mown (by hand or mechanically) be relatively free from bushes, large weeds, stumps, projecting stones, termite mounds, pig-holes and other obstacles to mowing and raking. It is absolutely essential that this be taken into account when haymaking is proposed in a new area. In tropical areas, termite mounds are a big nuisance, and are soon rebuilt after levelling. For mowing by sickle, obviously, levelling is less important.

Drainage and irrigation

Hay meadows are often liable to localized waterlogging; drainage may be desirable to improve herbage growth, facilitate access at harvest time and reduce infestation by rushes and other undesirable plants.

Various types of irrigation and water-spreading are used in traditional systems, usually in spring. In parts of Russia and Mongolia, spring water is spread in the cold weather, when it forms ice-sheets; these provide supplementary moisture in the growing season. This technique is discussed in the Mongolian case-study.

Fertility maintenance

Haymaking is a very extractive form of land use, because all the minerals in the crop are exported, unlike grazing, where much of the fertility is recycled through animals' excretions. Continued cutting from the same area, therefore, means that, unless adequate maintenance fertilizer is applied, yields will drop rapidly over time and stabilize at a very low level.

Dung is rarely returned to hay-fields; that which is recovered is used on the crop land or as fuel. Sold hay is, of course, a severe loss of plant nutrients to the overall farm system. Herbage generally responds well to fertilizer, but the economics of its use on natural grass has to be studied before use; in semi-arid conditions with unreliable rainfall, fertilizer application is risky. Where rainfall is reliable, fertilizer can be applied sufficiently ahead of the haymaking season to assure an adequate crop. Nitrogenous fertilizer is the most commonly used, but - over time - balanced fertilizer application becomes necessary. Where legumes are present in quantity in the herbage, as in some Mediterranean pastures and high-altitude Asian meadows, phosphatic fertilizer will encourage their growth and thus improve hay quality. The effect of phosphorus is slower and less spectacular than that of nitrogen, so nitrogen is generally by far the most popular.

Seasonal closure and rotation

The pasture must be closed to grazing for sufficient time to allow growth of the hay crop; there are, of course, many variations on how this is done. Fields may be only mown; but often they are grazed at the beginning of the growing season when feed is scarce, and then closed until after the hay harvest. Usually a single cut is taken, but, occasionally, on very high-yielding meadows, two may be possible, but fertilizer might be required. Heavy grazing early in the season is generally detrimental to pasture growth, but often is resorted to when no other source of feed is available. Good growth is necessary on land reserved for haymaking and every effort should be made to protect hay fields at the start of the season, until their herbage is well enough developed to stand grazing. Fields which are mown year after year often show declining yields and degradation of the floristic composition of the herbage. It can be advantageous to rest fields from hay periodically, grazing them for a season or two.

HAYMAKING

Techniques and equipment used are described in Chapter II. The time of mowing is dictated by both the weather and herbage growth; the aim as always is to make hay when the herbage is at its best and the weather suitable for curing hay. These two conditions do not always coincide and while some manipulation of grazing to shift the date of herbage maturity may be possible, this is less than with sown fodder. Suitable weather is the over-riding consideration and this is taken to its most extreme in some parts of the Himalayas, where haymaking is delayed until the rains are over - and the herbage very mature indeed.

Late harvesting is frequently deplored by technicians in monsoonal and tropical situations, as noted in several of the case-studies. It is often not clear, however, how earlier harvesting and drying could be successfully attained. Much of the natural hay is made on poorly-levelled, often steep, land, using primitive manual tools and in monsoon climates, so mowing is pitifully slow and could not be mechanized; no artificial drying facilities are available and would not be economic. In such climates it is likely that hay will continue to be made at the start of the dry season. As soon as it is dry enough the crop (loose or baled) should be removed from the field and stored to allow re-growth of the aftermath and avoid damage by cocks or stacks of bales.

Figure 24. Carrying bundles of hay for further drying (Gujarat, India)

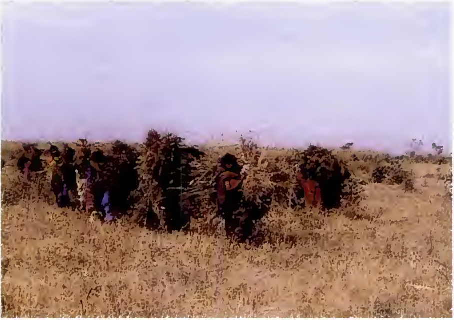


Photo: Ian Lane/C.S. Pandey

Yield estimation

Techniques for measurement of herbage yields are described in many textbooks[1]. An estimation of the available herbage, even if well done, is not, however, a useful guide to the amount of hay which will be produced. Much depends on the skill applied to haymaking - and the weather. Estimation by weighing or volume of the gross production of hay at time of storage, is much more likely to give useful information than sampling of green herbage, and at least provides a figure for the total available. Natural hayfields, especially in hilly conditions, are often irregular in shape and unsurveyed; estimates from sampling are meaningless if the area mown is not known precisely. Sampling of hay for quality analysis should be done on the made hay, not on the herbage from which hay is to be made! If only the standing herbage is sampled, losses in quality inherent in haymaking (leaf loss, leaching, transpiration) will not be accounted for.

Natural hay as a cash crop

Dried natural herbage is harvested in many areas and sold as hay or as fuel. Often in semi-arid areas, especially in *Artemisia*-dominated pasture, sub-shrubs are uprooted and sold as fuel in towns and villages. This destruction of rootstocks for fuel is a major cause of degradation of pastoral vegetation throughout much of the semi-arid regions.

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[1] For example: Brown, D. 1954. *Methods of Surveying and Measuring Vegetation.* CAB; Hodgson J., et al., (eds) 1981. *Sward Measurement Handbook.* British Grassland Society; Ivins J.D. (ed) 1959. *The Measurement of Grassland Productivity.* London: Butterworths; t'Mannetje, L.H. (ed) 1978. *Measurement of Grassland Vegetation and Animal Production.* CAB.

CHAPTER VIII

CHOICE OF HAY CROPS

Individual crops, their adaptation and cultivation are described in Chapters III to VI. Fodder is a crop with a wide range of specific substitution, and adapted species and cultivars are available for all agricultural zones, so hay crops should be chosen according to:

- local agro-ecological conditions;
- the farming system;
- the season when haymaking is to be carried out; and
- the use to which the hay will be put.

The level of technology influences crop choice and haymaking methods. Crops which require conditioning to accelerate drying, for example, are less suited to manual and simple implements, while fully mechanized systems can handle them.

CROPS, CULTIVARS AND CLIMATE

When choosing crops and cultivars to suit local climatic and soil conditions, the cultivar or ecotype is as important as the species. It is necessary to find adapted cultivars for each situation, and they must be screened locally before widespread field use if they are not already proven. Local practice, seedsmen and information from research units should be consulted at the outset of a fodder development programme. There is usually a surprising amount of information available. Cultivar names are mentioned in Chapters IV to VI, usually referring to specific situations, but these are for illustration only. On-the-spot screening is necessary before crops can be recommended firmly. A range of cultivars, and sometimes crops, with different maturities may be desirable to extend harvesting over a wider season and spread risks.

Some species have very wide natural ranges: cocksfoot, for example, is found from North Africa northwards to the limit of cultivation in western Europe; Mediterranean ecotypes have their main growth in winter and are dormant during the long, very hot summers; northern ones are summer-growing and winter-dormant. Perennial ryegrass behaves in the same way. Cultivars of lucerne have been developed, during the crop's long domestication, adapted to situations which vary from oases on the Saharan fringe, through temperate zones, to very cold, high-latitude and high-altitude sites. In all cases, therefore, it is not only the species of fodder which must be chosen, but the cultivar or ecotype to fit the agro-ecological conditions where it is to be grown, and the use for which it is intended.

When introductions are to be made, information on adaptation in areas of similar climate and farming system should be studied. Similar does not, of course, mean same, and such studies are only a guide to choice of cultivars for a testing programme, not for bulk seed buying. Seed catalogues are useful, but should be used as broad guides when assessing the possible performance in a country other than that of the catalogue's origin. Some ecotypes are excellent for grazing but much less suitable where hay-making is the prime consideration; the overall use and management of a pasture must be considered when choosing the correct cultivars.

The case study on the Altai reports the total failure of a range of "cold-tolerant" varieties of lucerne chosen after a serious study of available literature: the probable reason was that the Altai has little or no snow in winter but very low temperatures and often wind; most areas where lucerne is bred for cold tolerance are snow-covered in winter. Many failures of annual medicagos selected from Mediterranean material in Australia for Australian conditions, and then re-introduced to North Africa and western Asia, indicate the need for local screening.

The concept of analogous climates is, nevertheless, useful when searching for new crops or cultivars of an established crop. Analogous climates are those in which all elements are similar. It is reasonable to assume that crops and cultivars are likely to succeed in areas of climate similar to that in which they are already successfully grown, although this does not take into account such factors as disease challenge. Some "factor substitution" can be taken into account when comparing climates: altitude can compensate for latitude in control of temperature (away from the modifying influence of the sea or other large bodies of water, there is a fall of a little over 1°C per 200 m increase in altitude); temperature or cloud cover can affect the rainfall needs of a crop, and so on. These substitutions may not always work in a straightforward way, as high latitude crops at high altitudes in the tropics may be affected by photoperiodism or lack of chilling, but these are not serious considerations in fodders.

Sometimes, usually in the context of development projects, fodders of "high feeding value" (under conditions elsewhere) have been tried and re-tried under totally unsuitable conditions; emphasis on what are essentially grazing crops in areas where the farm size is only suited to cut-and-carry is frequent. The crops "introduced" usually reflect the early experiences and training of the technicians involved. This has been demonstrated very often, such as with lucerne under warm humid conditions on acid soils, or ryegrass and white clover where soil fertility is inadequate and summers too hot.

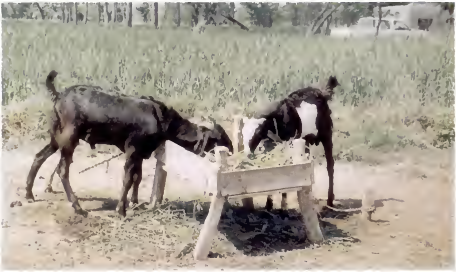
Availability of seed may, unfortunately, be a determinant factor in crop choice in some developing countries. Frequently, the research has been carried out and adapted cultivars identified or developed locally, but multiplication to commercial scale has not followed. In any extension work to develop hay from sown fodder, it is necessary not only to recommend the correct material but also to ensure that the seed is available commercially. While much crop improvement is, no doubt, required, the first and most important step is usually to make use of the cultivars and ecotypes that have been proven locally and to assure a sustainable supply of clean, healthy seed.

FACTORS AFFECTING CROP CHOICE

The existing farming system

This is of paramount relevance. Small-scale farms that rely on manual labour or very simple mechanization may have to use crops that differ from those of fully mechanized units. Overall labour and input availability within the system will affect many decisions. Unless grown specifically for sale, hay should be developed or introduced to complement existing feed - alongside grazing, crop residues and by-products - in the context of the type of livestock production being undertaken. Large tracts of irrigated farmland in southern Asia and Egypt, mostly managed in small-scale farm units, have little or no grazing, yet they support a very large population of milch and draught animals; there, fodder production has an important role in the cropping pattern, since green feed is essential to complement the roughages which form the bulk of the animal's diet. Personal preferences play a part. Thus, shaftal is preferred to the higher-yielding berseem in southeastern Afghanistan, as its shoots are a winter vegetable, while hairy berseem is not palatable to humans.

Figure 25. Stall feeding of goats in an intensively irrigated system with no pasture (Punjab, Pakistan)



Availability of crop residues

In many developing countries, especially those with well-developed arable production and limited grazing, the bulk of the feed for ruminants is crop residues. These, apart from the haulms of a few legumes, are coarse roughages and, even for maintenance of adult stock, will require supplementation. Green forage and good hay will supply the vitamins and minerals which the straws and stovers lack; for hard work, fattening and dairy production, concentrates will be required in addition. The aim should be to determine how best hay and green fodder can be used as a complement to a feeding regime based on the farm's overall production. Lucerne and clover are popular for hay in semi-arid Asia because it is largely used to supplement straw in winter. The quality of the crop made into hay must be appreciably higher than that of freely-available crop residues. This seems self-evident, but hay from coarse, over-mature tropical grass is little better than straw or stover. A project in southern Africa found that a "fodder" bulrush millet (*Pennisetum miliaceum*) was by far the highest-yielding forage crop - but it did not become popular for dry-season use. On analysis, the "hay" was no better a feed than the plentiful local stover.

Straws and stovers have often been neglected as feed sources in mechanized farming, especially since the availability of inorganic fertilizers reduced the importance of farmyard manure in production systems. Interest has increased greatly in recent years, helped by modern methods of treatment to improve intake and digestibility, and improved handling and storage. The first step in improving any residue-based feeding system is, of course, to optimize the quality of the straws and stovers concerned by careful harvest, drying and storage. Treatment is possible to improve their palatability and digestibility; this is discussed further in Chapter IX. Particular care should be taken over high-quality residues like legume haulms, groundnut tops and sunflower heads if the weather at harvest allows their proper drying.

Farm size and level of technology

Two main farm types can be distinguished according to holding size: (i) farms large enough to use grazed pasture; and (ii) small farms where fencing and grazing is not a realistic option. The three levels of technology were discussed earlier. Mechanization varies, of course, from simple, animal-drawn machines, to the most sophisticated modern equipment, but these are differences of degree. Small farms often rely more heavily on crop residues and cut-and-carry green feed than do mechanized ones, but, in suitable areas, will grow forage specifically for hay, and especially in semi-arid areas where lucerne can be grown. They will also make hay from any suitable natural vegetation if available. Where winters are severe, especially if the pasture is snow-covered, haymaking is common among small-scale farmers. In the drier parts of the Himalaya-Hindu-Kush region, and much of semi-arid Asia, legume hay is a very widespread crop, and indigenous, manual methods of harvesting are well adapted to curing the crop without undue leaf loss. The case studies from Afghanistan, China (Altai) and Turkey describe some of them. Large, fully mechanized farms have a wider choice of technologies and, in addition to haymaking, often from pasture, they can also make silage from pasture, forage crops and cereals; their size allows a combination of grazing and conservation in the management of forage fields. In the drier parts of the monsoonal lands there are indigenous technologies for drying crops such as bulrush millet, maize and sorghum as a kind of hay; this making of *kadbi* often merges into the conservation of crop residues.

The livestock production system

The stock rearers' needs may be to assure over-wintering (or dry-season) survival, for maintenance, or for production. If hay is for sale, the considerations differ between specialized markets for high-quality hay, and bulk markets, where there is little premium paid for quality. The type of stock has a strong influence on the crops to be conserved. Dairy cattle, riding and working horses, and fattening stock require higher quality feed than do store stock and work oxen in the off season. Camels and goats will accept dried shrubs, which other stock would not eat. Buffaloes consume rice straw more readily than do other species and, with a minimum of supplementation, will produce some milk or work off a diet which is mainly rice straw. Coarse bush hay is sought after by dairy producers in India, while stuff of similar quality would be scorned elsewhere; presumably it has two uses: as a near survival diet in poor areas and as a roughage source in concentrate-based dairy systems. Collection of poor natural grass is associated with acute shortage of dry matter and with climates where the cultivation of good hay is not easy, as shown in the case studies on India and the Sahel. Graziers in areas where the vegetation is not covered by snow in winter, or in tropical and sub-tropical dry seasons, may find it acceptable to have their stock lose some weight in the lean season; they may find that other strategies for lean-season feeding, such as fodder banks and standing hay, may be more remunerative. For areas with hard winters or where standing forage is not available, however, conserved feed is essential.

Soil fertility maintenance

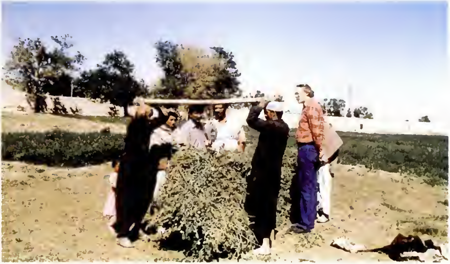
Hay, especially legume hay, has long been recognized as a fertility-improving crop within arable rotations. The leguminous component fixes nitrogen, some of which remains for following crops; most fodders give very good ground cover and thus help suppress weeds, although the increasing use of inorganic fertilizers and herbicides in commercial farming has somewhat reduced the role of fodder and pasture crops in fertility maintenance. Legumes are still widely used in small-scale farm agriculture in parts of Asia and North Africa, and one reason is their fertility-restoring qualities. Legume-based cereal-fallow rotations are common in winter rainfall areas. Such land-hungry countries as Pakistan, India and Afghanistan cultivate appreciable quantities of fodder (much of it under irrigation): 19% of the arable land in Pakistan and 5 - 7% in India are used for fodder production. A recent study on Afghan agriculture indicates that the fodder area (mostly lucerne and clover for hay) is over 5%, despite the troubles which have disrupted local agriculture and seed supply.

The use to which the hay will be put - on-farm use or for sale

For ***hay for on-farm use,*** the aim is usually to make a high-quality product to complement the other roughages available (which are usually high in fibre and low in protein, vitamins and minerals) to give maximum impact on livestock performance. Frequently in production systems, there is plenty of dry matter (rice straw, sugar cane tops, stovers) available during the season of feed scarcity, but their quality is sub-maintenance and requires supplementation.

With ***hay for sale,*** the hay is produced and sold for many different reasons. This can vary from the need for quick cash, such as when the Anatolian farmers sell their meadow hay while feeding their stock on straw, to sowing hay for specific markets. Hay may be produced because conditions are particularly favourable for supplying a quality market; or arable farmers may fit a hay crop into their rotation where they do not want to be involved in livestock rearing (especially where fencing or water supply costs might be problematical), but where a ready local market for hay exists. For example many cereal farms in northern Tunisia produce oat hay for sale to transhumant herds or to the stock-rearers of the desert fringe - these farms already have the equipment for land preparation and sowing, the crop matures at a season when field drying is easy, so only simple mowing, swath-handling, and baling equipment is needed in addition. Frequently in developing countries, little premium is paid for quality hay, so the emphasis is on bulk where cattle and small ruminants are concerned.

Figure 26. Contractor buying fodder for sale in town (Quetta, Pakistan)

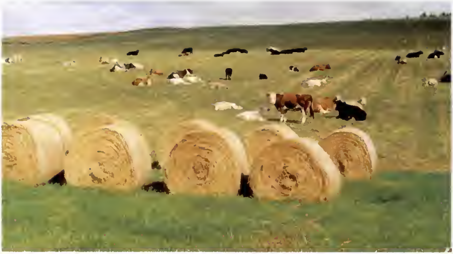


Hay for horses is an important trade. The situations vary from the urban draught horses and donkeys of Asian cities, to the recreational ones of industrialized countries. Horses and their owners have distinct preferences for high-quality hays from a few crops: lucerne is favoured everywhere, oats and timothy are greatly appreciated in western Europe and North America, and teff in South Africa. The case study on Pakistan describes how oat as a hay crop has expanded greatly in recent years because it is much cheaper to transport to distant urban markets and is less perishable than fresh feed.

Hay from grazed swards

Herbage may be set aside for haymaking because there is more feed on offer than the herd can graze; also, if herbage quality is such that there is a high danger of physiological disorders like hypomagnesia or bloat, then it may be made into hay, which can be safely fed. Tropical and subtropical fodders that at certain stages of growth contain dangerous quantities of cyanogenic substances can be safely fed once made into hay. Sorghums are notorious for toxicity when under stress, but several other tropical grasses, including *Cynodon,* can be affected.

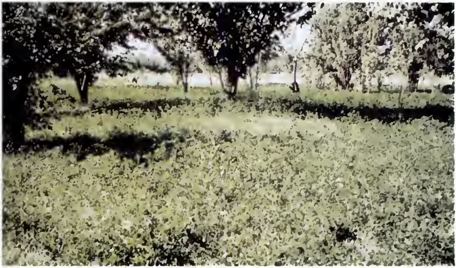
Figure 27. Mixed use of pasture: bales of hay drying at the field side behind an electric fence while the re-growth is grazed (Dunecht, Scotland)



Grass-legume mixtures

In humid-temperate areas, hay is often made from sown mixtures of grasses and clovers, and these are usually also used for grazing. The legume should, through biological nitrogen fixation, supply protein to the livestock and - both directly and through the faeces and urine of the grazing livestock - provide nitrogen to the companion grass. This presupposes that the legume is well established, nodulating vigorously with the appropriate *Rhizobium*, and present in large quantity. Legume seedlings are very susceptible to shade when young, as adequate photosynthesis is essential both for the growth of the plant and to supply the energy that the root-nodule bacteria require for N-fixation. At the establishment stage, the linear, sun-seeking leaves of grasses quickly shade young legumes unless grazing or other defoliation so manipulates the canopy that the legume is favoured. *Trifolium repens,* the commonest legume of temperate grazing mixtures, is very sensitive to faults in early management (sward establishment is discussed in Chapter III). It is, however, a common, and undesirable, practice to let the first growth of a new mixture grow up for hay (sometimes with a top-dressing of nitrogen): the clover seedlings are mostly stifled and the few which survive are inadequate to have any real effect on the sward. The sward, therefore, becomes less productive and fodder quality lower than had a proper legume balance been obtained. Excellent hay can be produced from mixtures where the legume has been allowed to establish fully. Fields should therefore be managed to encourage the legume and maintain its vigour.

Figure 28. Lucerne as an undercrop in an orchard (Khost, Afghanistan)



Undercropping in orchards

Leguminous fodders are frequently sown as winter cover crops in orchards and vineyards, especially in Mediterranean climates and in irrigated semi-arid areas. In some manual systems, these are mown and made into hay. Lucerne and shaftal are widely grown in orchards in parts of Pakistan (Balochistan and the Northern Areas) and Afghanistan, where haymaking from orchards is common.

The forage keeps down weeds, utilizes the land and water for a longer season than the fruit, and adds some nitrogen to the system.

LEAN SEASON FEEDING STRATEGIES

When planning a farm's fodder production and conservation, hay is not the only solution for lean season (winter, dry season) feeding, and alternative strategies should be considered before coming to a decision. Some are considered briefly below.

Year-round green feed

In some favoured climates, either humid-temperate or under irrigation, green fodder supply can be maintained throughout most of the year but, inevitably, there are seasonal variations in availability and quality. Even in the great irrigated fodder-producing tracts of Egypt, India, and Pakistan, the green feed supply is usually insufficient in winter and at the height of summer. At these seasons, stock rations are often largely composed of straw and are inadequate for reasonable dairy production. Year-round grazing is widely practised in tropical countries and in pastoral systems. In the milder temperate countries, reasonable grazing can be provided during most of the year; such grazing systems, however, must either be supplemented seasonally or accept losses of production and condition during periods of low feed availability and quality.

Stay-green fodders

In the medium-altitude tropics, Napier grass (*Pennisetum purpureum*), carefully managed so as to go into the dry season in a leafy state, can provide reasonable forage for several months (rationed). This was used widely in commercial dairy farming in western Kenya, usually in rotation with maize. Sugar cane is unusual among the grasses in that it stores energy in its stem and has its highest content of digestible matter during the dry season. It is a highly digestible energy feed, but one which of course requires supplementary protein and minerals. Cane juice can be used in monogastric rations and the fibrous residue fed to ruminants.

Standing hay

Reserving some areas of pasture during the period of growth for later use is an ancient and widespread practice in temperate and semi-arid grazing systems (e.g., the *hema* system of the Near East). Its effectiveness depends largely on the quality of the stand-over feed. In the better-watered tropical grasslands, however, the quality of the senescent, dried-off grass is so low and its palatability so poor that it does not even provide a maintenance ration; then the old vegetation may be burnt off to encourage a small but nourishing re-growth. In cold, semi-arid areas the quality of the standing (often frozen) feed is better and herders are usually unwilling to give hay to the main herd, since it encourages them to hang about looking for more and to forage less. Hay is reserved for weak stock to help them survive the winter, and for riding and milch animals.

Fodder roots

Root crops grown for winter feed were formerly very widely used in humid-temperate countries, although their importance has diminished somewhat as mechanization increased and silage-making techniques and equipment improved. Turnips (*Brassica rapa* var. *rapa* (syn. *B. campestris*), swedes (*Brassica napus* var. *napobrassica*) and fodder-beet (*Beta vulgaris*) are the main ones, although large fodder radishes are important in parts of temperate Asia. These are crops of arable land in mixed farming systems and constitute a "cleaning crop" for weed control in rotations. Their moisture content is very high (90%) so - like silage - they must be used close to where they are produced. Roots may be grazed on the field, especially by sheep, but in colder climates are usually stored in clamps or sheds for late winter and early spring, when they are most needed.

Fodder banks

These describe blocks of cultivated fodder specially set aside to provide high-quality dry-season grazing to supplement the poor natural herbage on offer. They are used in grazing systems. Herbaceous legumes are widely used for this purpose, and under tropical and subtropical conditions, *Stylosanthes* spp. are notable. Fodder banks must be managed throughout the year to ensure that they enter the dry season in suitable condition. If they are left ungrazed during the growing season the legume component will be suppressed and the bank will degenerate to old grass.

Fodder trees and shrubs

These can sometimes provide green feed, and - most importantly - high quality fodder during tropical dry seasons and mild Mediterranean winters. *Leucaena leucocephala* is well-known under sub-humid to humid tropical conditions, and *Atriplex* spp. have been widely tried under Mediterranean semi-arid conditions. Fodder cactus (*Opuntia ficus-indica*) is used in tropical (NE Brazil), subtropical (southern Madagascar, South Africa) and Mediterranean (North Africa) semi-arid zones. Where shrubs and cactus are used as feed reserves for bad seasons they must still be managed and exploited regularly, otherwise they become woody, unproductive and of low feeding value. Wild and semi-domesticated tree forage is lopped and stall-fed in many areas when other feed is very scarce.

Lopping is especially prevalent in the low and middle altitudes of the Himalayan zone, where useful fodder-producing trees, some planted, are kept within the arable land, and forest forage also harvested; it is done seasonally as a reaction to acute feed scarcity rather than because of the inherent qualities of the herbage.

The fruits of wild trees are grazed or licked off the ground by livestock, and the acacias of the African savannahs are important in this respect. Some pods are harvested for use as concentrate feeds, either from protected and managed wild trees (e.g., *Acacia albida* in the Sahelian zone), or cultivated, like the carob (*Ceratonia siliqua*) in the Mediterranean region, and algaroba (*Prosopis juliflora*) in southern America.

Concentrates and bought-in feed

Concentrates and bought-in feed are, of course, essential in most intensive production systems, especially dairying, but are widely used in some areas by pastoralists to help assure survival of stock through the winter. Some concentrates are by-products of off-farm processing of crops, including press-cakes, brans, milling residues, marcs and pomaces; others are cereals and pulses specifically grown for use as feed.

Drying of non-vegetable material

Various animal by-products (notably blood, fish meal and bone meal) are dried and fed to livestock, but these are usually incorporated into concentrate feeds. An unusual tradition of using dried fish as a dry-season supplement persists on the southern littoral of the Arabian peninsula where very small fish - "sardines" - occur in great shoals seasonally and are netted, then sun-dried, and used to supplement poor stover, dry standing grass and hay. This is an old tradition, for it is remarked on by Marco Polo in the 13th century:

> "and here is something else that may strike you as marvellous: their domestic animals - sheep, oxen camels and little ponies - are fed on fish. - *shihr*. The fish on which the animals feed are very small and are caught in March and April in quantities that are truly amazing. They are then dried and stored in the houses and given to the animals as food throughout the year."

and Ibn Batuta in the 14th century at Zhafar (Dhofar): "Une chose étonnante, c'est que les bêtes de somme s'y nourissent de ces sardines, et il est ainsi des brebis." The tradition continues - always with a slight danger of botulism through imperfect drying - with a modern variation in that cardboard cartons are now collected from the markets and torn up as a cellulose base to the diet; they are probably no worse feed than the over-ripe hay of mainly *Themeda australis* and the few millet stalks available.

HAY CROPS FOR DIFFERENT CLIMATES

No classification is wholly satisfactory in all aspects. The zones used below follow those adopted by the International Grassland Congress at its 1993 meeting. Strict definitions and latitude limits are not very useful in the fodder context, and small local variations in altitude (and in aspect at higher latitudes) can make appreciable differences to local climate. Tropical climates are usually taken as those where annual and monthly mean temperatures are above 20°C; subtropical has 4 to 11 months above 20°C; temperate has 4 - 12 months at 10 - 20°C and the rest cooler; and polar implies 12 months below 10°C. For annuals, it is the temperatures and length of the growing season which matters, so in continental climates with cold winters but hot summers, hot-area fodders can be successfully grown. The number of expected frost-free days is a useful, but fairly variable, parameter, and the date of the first and last killing frosts are important. Within temperature groupings, moisture availability is a sub-dividing factor. Soil fertility, acidity and drainage are, of course, determining factors; waterlogged and seasonally waterlogged soils are treated apart in each main climatic group. The season when the crop will be at its best from the nutritional point of view is critical, as it is essential that it coincide with expected weather suitable for haymaking. The climatic data in most of the examples below is from FAO (1987); stations familiar to the author have been used wherever possible.

HUMID AND SUB-HUMID TROPICAL AND SUBTROPICAL ZONES

Hay is not usually produced in the humid tropics and ruminant livestock are not as common there as elsewhere, but draught animals are important in Asia; in Africa, disease and tsetse fly restrict cattle production in this zone. The dry season is short, so beef and breeding stock will usually be able to maintain themselves from grazing, with little loss during the short dry season. For dairying or fattening, it is usually possible to have cut-and-carry fodder for most of the year to supplement grazing. Natural grazing is not usually an important feature of the vegetation (although there may be cogongrass (*Imperata cylindrica*)) and its quality is poor. Valuable grazing is available under tree crops in this zone; its management is discussed in detail by Reynolds (FAO, 1995a). Fodder banks and leguminous trees such as *Leucaena* may be used as protein supplements. For dairy production, small-scale farmers can use cut-and-carry fodder from crops that stay green, for example, Napier grass and *Leucaena*. Silage production is an option for larger dairies. While cropping is widespread in this zone, the drying and conservation of straws and stovers, of which rice is among the most important, is difficult for climatic reasons. Straw treatment with ammonia or urea is a possible means of conservation as well as improving digestibility. It is usually very difficult to dry the haulms of grain legumes satisfactorily.

Sub-humid tropics

Ruminants thrive in this zone. It is usually possible for beef cattle (unless being fattened for sale at that time) and breeding stock to pass the relatively short dry season at pasture, with little or no supplementation. Grazing is more widely available and of better quality than in the humid tropics. Cereals are important, and their straws and stovers are a major dry-season feed.

Low altitude zone

Here a wide range of tropical grasses and legumes, domesticated mainly over the past half century, can be grown according to the soil and moisture situation. Considerable progress has been made in developing tropical pasture legumes over the past forty years or so, but they are better suited to grazing than to haymaking. There are as yet no equivalents of clovers or lucerne (although the latter can be grown in favoured tropical and subtropical sites) for tropical haymaking. Twining legumes combined with grasses can be made into hay, but with serious leaf-loss. The hardy *Stylosanthes guianensis*, which has been the backbone of much tropical work, is extremely useful as a standing green feed in fodder banks, but is very difficult to make into hay and usually goes black before it dries. Tropical hays are, therefore, based on grasses and some pulses. In all but the driest areas, grasses which are quick-drying should be chosen: Rhodes grass and Guineagrass are among the best; teff can be grown over a wide range of soils and climates, but only in South Africa has it become an important hay. On sandy soils at the driest end of the rainfall range, buffelgrass (*Cenchrus ciliaris*) is suitable.

Medium altitude zone

This is the area above about 1600 m. A wide range of pasture plants are available for this zone, and fodder cereals can be grown for hay or silage. This zone is too high for really vigorous growth of most of the "tropical" legumes, including *Stylosanthes guianensis*, and the fodder bank approach is less developed than in the low-altitude tropics. Large fodders (Napier grass, Guatemala grass) are used by small-scale farmers for cut-and carry, and can also be used as fodder banks for dry-season grazing. Haymaking presents few problems for mechanized farms, although it must be seasonal and combined with grazing. Often in the region, rain falls mainly in the afternoons, so it is advisable, therefore, to mow early and turn as soon as possible: with a clear sky it should be possible to get the herbage dry enough to put it into windrows or cocks (and sometimes to bale it) before the afternoon storms. Suitable hay crops include *Chloris gayana, Cynodon* spp, *Panicum maximum* and, in the higher parts, *Bromus unioloides*. Where soils are neutral to alkaline and humidity low, lucerne can be grown, but its adaptation in the tropics is very localized. In Kenya, for example, lucerne has been grown commercially, with great success, in the Lake Naivasha basin for most of the century, but outside that microclimate at similar altitudes it is not a viable crop. Sudan grass and fodder sorghums grow well and, with suitable machinery, can be made into satisfactory hay. Hay is usually for dairy stock.

Crop residues from cereals have a high potential in this zone, especially maize and sorghum stovers; conditions are too humid for the easy drying of the haulms of beans and other pulses.

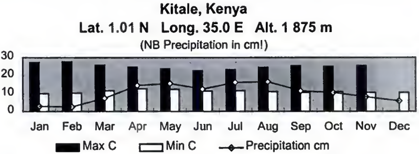


Figure 29. Monthly precipitation and temperatures in Kitale, Kenya

High altitude tropics (above about 2 750 m)

Temperate crops thrive at high elevations, especially under good rainfall, and haymaking is usually not difficult. Where there is large-scale farming, ryegrasses, fescue, cocksfoot, *Phalaris* spp. and clovers (*T. pratense, T. repens* and *T. subterraneum* all grow well and produce seed) can be grown without difficulty if fertility is adequate (Morrison, 1966), as can oats and vetches. In areas of low atmospheric humidity and good fertility, lucerne can be used.

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Temperate pasture and fodder crops were widely used in the highest agricultural zones of Kenya in the 1950s and 1960s (see Figure 30 for a typical station) but have largely fallen out of use with changes in the farming pattern. Temperate forages are used at similar altitudes in the Andean region.

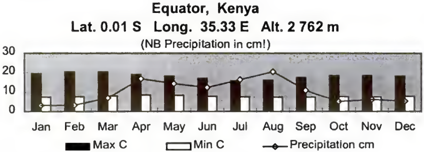


Figure 30. Temperatures and rainfall in the high-altitude tropics (Equator, Kenya, 2 762 m)

Hay from seasonally waterlogged tropical land

In the tropics at low and medium altitudes, Pará grass (*Brachiaria mutica*) grows well in wet conditions but is rather coarse and does not dry easily. *Panicum coloratum*, its variety *P. coloratum* var. *makarikariensis* and *Setaria sphacelata* are suitable for seasonally waterlogged land; these grasses are suitable for hay if the land on which they are grown is dry enough at harvest time. *Echinochloa pyramidalis* grows in areas of seasonal waterlogging and flooding, and is used for haymaking in southern Africa. *E. scabra* (*E. stagnina*), the Bourgou of the internal delta of the Niger, is widespread in the old-world tropics - it can withstand flooding to up to a metre in depth, and is grazed after the floods fall. *Panicum antidotale* withstands seasonal waterlogging in the semi-arid tropics. Nile Grass (*Acroceras macrum*) has been cultivated experimentally, with promising results in southern and eastern Africa.

Legumes for seasonally waterlogged land are not common. *Aeschynomene* spp., *Sesbania sesban* and *Macroptilium lathyroides* can be used as browse and grazing, but are not well suited to haymaking.

Hay on saline soils

Rhodes grass will grow on quite saline soil and is a very easy crop to make into hay. It can be included in mixtures where there are patches of salinity as the

Rhodes grass will cover the saline spots while the mixture thrives on the better land. This has been used successfully with lucerne fields under semi-arid conditions.

Coloured Guineagrass and makarikari grass (*Panicum coloratum* and *P. coloratum* var. *makarikariensis)* are both tolerant of salinity and make good hay grasses. *Diplachne fusca* is very salt tolerant, and has been used for reclaiming saline irrigated land, but requires a lot of irrigation water; it is only a moderate hay. Among the coarse fodders, bulrush millet is quite tolerant of salinity, and sorghum only slightly less so.

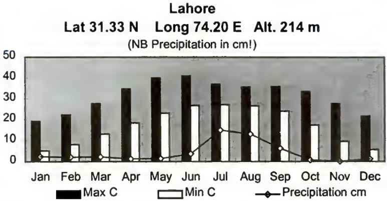
Some legumes are salt tolerant: *Melilotus indica* is highly tolerant, as is *M. alba* (although the latter is only suitable for medium and high altitudes in the tropics), and can be made into hay, but with care because of the danger of toxicity in poorly prepared melilotus hay! *Sesbania sesban* is used for reclamation of saline land and as a forage, especially for goats, but is usually browsed directly rather than being dried. The pod-bearing algaroba (*Prosopis juliflora*) is very well adapted to saline soils.

DISTINCT WET-AND-DRY SEASON ZONES

There are two main climatic groups within this classification: those tropical and monsoonal lands with warm-season rainfall, and the Mediterranean lands, where precipitation is during the cool season and the summers are dry. The flora and fodder crops of the zones differ greatly.

Monsoonal areas

The monsoons are, in the strict sense, winds which affect the climate of India and surrounding lands: the northeast monsoon from October to April is the dry season; the southwest monsoon from April to October is the main climatic event bringing heavy rains to the region from the Indus valley to the East Indies. Lands with a monsoonal rainfall pattern, i.e., a long dry season with an intense rainfall peak in summer, cover a very large area in the tropics and subtropics of Africa and Australasia. Whyte (1968) classes the grasslands of the Sahelian and Sudano-Sahelian zones of Africa from the Atlantic to the Red Sea as monsoonal, along with those of the Sudan and the countries of the Horn of Africa. Parts of southern Africa and the east coast of Madagascar also have a monsoonal rainfall pattern. Southern Arabia, Pakistan from the borders of Balochistan and NWFP, India, Nepal, Myanmar and much of Southeast Asia are monsoonal, as are



Queensland, the Northern Territories and part of Western Australia in Australia.

Figure 31. Monthly precipitation and temperatures for Lahore, Pakistan

In its wider application, monsoonal describes a large area of the tropics and subtropics which have a long dry season and a short, but intense, rainy season. The natural grasslands of the "monsoon" zone have a very seasonal production pattern, which results in a low potential for development of ruminant production unless supplemented from arable land. This is a difficult region for non-irrigated hay production. The peak of the rainfed crop, natural or sown, comes at a time of high rainfall and humidity, often with much cloud, so field drying is difficult. In hilly and forest areas much hay is made from natural pasture, but usually at the end of the monsoon, when herbage quality is very low indeed, even if drying is easier.

In much of this area, however, ruminant livestock are very important. Pakistan, India and Bangladesh combined have some 23% of the world's large ruminants (See Table 6) and 235 million sheep and goats - some 14.5% of the world total. Milk is a staple of the national diets. Most are kept on small farms. Some, especially small stock kept by pastoralists, must depend for much of the year on stubbles, crop residues, fodder in irrigated areas, and dried feed.

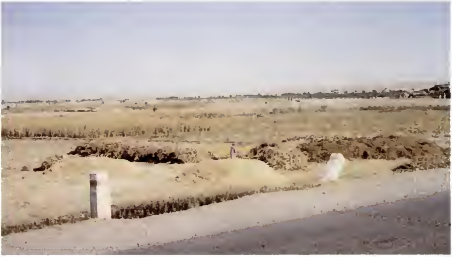
Table 6. Large ruminants in southern Asia (millions)

	Cattle	Buffaloes	Total Large Ruminants
India	196.5	73.7	270.2
Pakistan	17.4	14.4	31.7
Bangladesh	23.0	2.0	25.0
Total	236.9	90.1	326.9
As % of World Total	**18.5**	**64.3**	**23.0**
World Total	1 281.5	140.0	1 421.5

Source: FAO Animal Production Yearbook for 1989.

Lahore's climate (Figure 31) is typical of much of the irrigated tracts of Punjab, a region where dairying is extremely important. The climate is semi-arid but, with irrigation, growth continues for most of the year, with only a few weeks when temperatures are too low for most crops. The main feeds are green fodder and crop residues. A series of annual crops are grown to fit the wide seasonal range of temperatures: berseem, oats and mustard in winter; sorghums and maize in summer. Oat hay is now an important winter crop; dried sorghum and bulrush millet are conserved in autumn. Some lucerne is grown in the western part of the State, but mostly as an annual, since the monsoon brings disease and encroachment by rhizomatous grasses.

Figure 32. Crop residues as winter feed: wheat straw (in mud-plastered mounds), maize stover and mung (*Vigna radiata*) threshings (Gereskh, Afghanistan)



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Jhansi's climate (Figure 33) is typical of much of the higher rainfall lands of Uttar Pradesh, with eight months almost completely rainless and heavy precipitation from mid-June to mid-September. For much of the year, the grazing produces very little, but livestock are important for milk and draught in the local economy. Agriculture is rainfed, with little or no irrigation; holdings are small and unmechanized. Some poor and overripe hay is made on wasteland, but during the period when grasses (wild or sown) are at a suitable stage for conservation, the weather is unsuited to haymaking. Sorghum is grown to reach heading at the start of the dry season, then hand cut, field dried and stacked upright; it is chaffed before feeding to livestock.

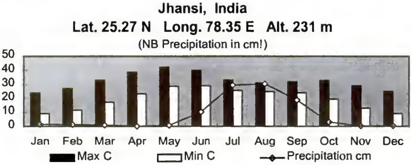

Jhansi, India
Lat. 25.27 N Long. 78.35 E Alt. 231 m
(NB Precipitation in cm!)

Figure 33. Monthly precipitation and temperatures in Jhansi, India

Sub-humid subtropics

Teff (*Eragrostis tef*) and weeping lovegrass (*E. curvula*) are very widely grown for hay in southern Africa. Dallis grass, star grass and fodder sorghums are suited to this zone. Where soil conditions are suitable and humidity low, lucerne is grown. Among the pulses, soya, cowpea and groundnut can be used for hay.

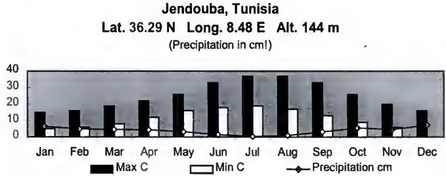
Saline soils in the subtropics

Rhodes grass, *Diplachne fusca, Melilotus indica* and *Sesbania sesban* are suitable for hay production, as are bulrush millet and sorghum.

MEDITERRANEAN LANDS.

The climate is characterized by the alternation of a rainy season in the winter months with a dry season in the warm months. Grassland production is very variable; normally it starts in autumn with the first rains, and continues but slows down during winter because of low temperatures; it speeds up greatly in spring to reach a peak, and then ceases at the end of spring due to dry conditions. The colder the area the longer is the winter gap.

Pastoralists in the Mediterranean lands have generally developed transhumance systems for their flocks (Papanastasis and Mansat, 1996). This zone has a very long tradition of fodder cultivation and haymaking and many well-adapted fodders. Where irrigation is available, hay can also be made in the hot months. In addition to the lands immediately adjacent to the Mediterranean sea, "Mediterranean" type climates with winter rainfall occur in parts of Australia, South Africa, the western USA, Chile and Argentina.



Jendouba, Tunisia

Lat. 36.29 N Long. 8.48 E Alt. 144 m

(Precipitation in cm!)

Figure 34. Monthly precipitation and temperatures for Jendouba, Tunisia

A wide range of fodder legumes is available. Lucerne is a prime hay crop on neutral to alkaline, well-drained soils, either rainfed or under irrigation. Sainfoin (*Onobrychis viciifolia*) is sometimes used where the soil and water supply is marginal for lucerne. Sulla (*Hedysarum coronarium*) thrives on heavy calcareous marls unsuitable for other legumes, so long as the area is not too frosty in winter - it is a coarse legume but a high yielder that requires careful drying.

Several clovers are adapted to the region: Berseem grows well where winters are mild; shaftal and crimson clover survive colder conditions. White clover requires summer irrigation. On salt-affected soils, *Melilotus* can be grown. Serradella (*Ornithopus sativa*) is sometimes used on sandy soils. Strawberry clover (*T. fragiferum*) occurs naturally where there is moisture at depth.

Pasture grasses suitable for haymaking and adapted to this zone are usually best suited to larger enterprises, where fencing and management of grazing is practicable. In well-watered areas, ryegrasses and *Phalaris aquatica* thrive where annual precipitation exceeds 500 mm. Tall fescue is very tolerant of waterlogging (although it also thrives on well-drained sites) once established; it can be combined with *Trifolium fragiferum* on wet land for grazing, but it is difficult to maintain the legume in fields managed for hay.

Arable fodders are well represented. Vetches and peas are hardy winter crops, and fenugreek is also used as hay. Most hay is grown in the cool season but, where moisture is available in summer, Sudan grass and fodder sorghums can be grown. Oat is a major hay crop, especially in North Africa, often for sale to transhumant flocks or for transport to the desert fringe, and it can be grown on most well-drained soils. Oat hay in Tunisia (Jendouba is a typical site - see Figure 34) is associated with mechanized cereal farming, as much of the equipment is common to both and is mainly done for sale, allowing the farmers to concentrate on crop production without incurring fencing and water-supply costs, and also enabling them to leave their farms and attend to other matters during the long, hot, dry summer. Carob is cultivated for fodder pods in some frost-free parts of the zone, with Cyprus a noted producer.

ARID AND SEMI-ARID ZONES

In arid areas, of course, all crops are grown under irrigation. Hay is a common crop in arid parts of Asia. Rainfed, sown hay in semi-arid areas is commonest on large farms, since yields are generally erratic through variations in rainfall. Lucerne can be grown on suitable soils. Teff is used for hay in South Africa, but nowhere else; buffelgrass can be grown in tropical and warm subtropical sites.

Irrigated forage production is traditional in oasis situations, lucerne being the major crop. In recent years there has been a great expansion of large-scale fodder production by sprinkler systems, often centre-pivots, to supply dairies and sporting livestock in the oil-producing countries of Arabia. Lucerne is a major hay crop; sorghums are suitable, as is Rhodes grass, which can be used with more saline water or on more saline land than can the others. These fodder and haymaking systems are highly mechanized and, in the sunny and dry climate, because curing is rapid, care must be taken to avoid shattering.

WINTER-COLD ZONES

Small-scale farm situations

Large areas of traditional pastoral land are in semi-arid to arid, temperate zones with cold winters and hot summers. Lucerne is the preferred hay of most of such zones, with sainfoin on the poorer soils. Sweet clover can be grown on land too dry or too saline for lucerne, and as a short-term fodder or soil improver. Birdsfoot trefoil (*L. corniculatus*) grows well but so far has only been cultivated experimentally under small-scale farm conditions. Ghazni (see Figure 35) shows typical conditions, as described in the case studies on Altai and the Northern Areas of Pakistan: all situations with irrigation and a hot growing season. Hay is an important component of production systems under such conditions. Grasses are not usually cultivated. Oats and vetch are suitable annuals. Where the thermal growing season is very short and precipitation low, as for Mongolia, natural hay is the usual choice.

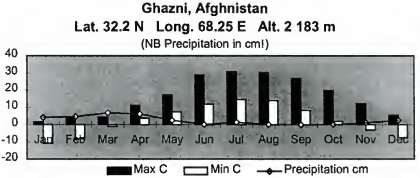


Figure 35. Monthly precipitation and temperatures in Ghazni, Afghanistan

Intensive temperate situations

Rainfall in temperate climates is spread throughout the year. A wide range of hay crops have been developed for this zone, since it was a forerunner in the modernization and intensification of agriculture and mixed farming systems. The many variations in climate can be split according to the severity of the winters and to whether the summers are hot or merely warm.

Temperate areas with hot summers

In areas with hot summers, crops such as maize and sorghum can be grown for conservation, although silage is now much more common than hay. Lucerne is grown where soil and humidity permit.

Temperate areas with warm summers

Where winters are mild and summers warm, the classical pasture grasses and legumes are grown, alone or in mixtures: Italian and perennial ryegrasses on fertile soils; timothy on heavy land; lucerne on well-drained neutral to alkaline soils; red clover or ladino clover in mixture; and cocksfoot in drier, hotter areas or on poorer soils. Mixtures which are both grazed and conserved are common. Oats and vetches are suitable arable fodders.

Cold winters and warm summers

Where winters are cold and summers warm, timothy (*Phleum pratense*) is the preferred hay grass and red clover or lucerne (according to soil) the main legume. Oats, sweet clovers (*Melilotus* spp.) and vetches can be grown. For waterlogged land, *Phalaris arundinacea* can be used; this grass has a very wide range of adaptation and, while extremely cold-hardy, is also part of the traditional hayfields of high-altitude Ethiopia.

CHAPTER IX
DRY CROP RESIDUES

Major field crops, especially cereals, produce large quantities of stem and leaf in addition to their saleable product, which is usually seed. The straw or stover is usually over half the harvestable vegetation of the crop. Such coarse roughages cannot be eaten by humans, but they can be transformed into economic products by livestock. Some cereals and pulse crops are also grown specifically for hay, and details of their cultivation as forage are given in Chapters III to VI.

Our subject here is the residues of field crops that are grown for purposes other than fodder. While these residues are coarse roughages, they are often no worse than, and possibly better than, dried, mature, tropical grasses. This should be kept in mind when dealing with small-scale agriculture in tropical systems: better straw harvesting and storage, with possibly urea treatment, may be cheaper and more productive than going to great trouble to harvest bush hay. Details of the feeding value of some residues are given later, in Chapter X.

Straw is the stems and leaves of small cereals; chaff is husks and glumes of seed removed during threshing (chaff is usually a richer feed than straw, but more difficult to feed because of awns, etc.). Modern combine-harvesters generally deliver straw and chaff together; other threshing equipment separates them. Stover is the field residues of large cereals, such as maize and sorghum. The leaves and stems of pulses are variously described as haulms or vines. Stubble is the stumps of the reaped crop, left in the field after harvest. Agro-industrial wastes are by-products of the primary processing of crops, including brans, milling offal, dal polishings, press-cakes and molasses. These are mostly concentrate or near concentrate feeds, but since they depend on processing rather than crop production, they are beyond the scope of this book. Brans from on-farm husking of cereals and pulses are fed to livestock or foraged directly by backyard fowls.

Straws and stovers have always been an important part of agriculture. Until the advent of cheap inorganic fertilizers and mechanization, they were an integral part of large-scale farming as feed for draught and other stock and litter for the production of manure, which was essential to the maintenance of fertility. At the small-scale farming and subsistence levels, agricultural residues have retained their importance, indeed, the importance is growing because of the ever-decreasing access to free grazing as cropping area expands. With changing production technologies in mechanized agriculture, straws were for some time thought to be of so little value that they were often burnt in the field. Environmental legislation, and the development of straw treatment to improve digestibility, has brought an end to straw burning in most developed countries, where it is now either fed to livestock or used for industrial purposes.

The change of land use from grazing to cereal production does not usually reduce the amount of roughage available for livestock, as the amount of straw and stover will be as great or more than the natural herbage previously on offer. In the vast irrigated lands which have been developed in arid and semi-arid areas (e.g., Asia, Egypt, Sudan) the amount of roughage from crops is vastly greater than the former production from natural grassland. Rice-based production systems yield large amounts of straw. Frequently, the change from extensive grazing to arable or mixed farming leads to an increase in the number of livestock kept. Many agricultural production systems are mixed, with both cropping and livestock, often multipurpose; with decreasing grazing availability, the stock rely on crop residues as the basis for their nutrition. It is essential, therefore, that these residues be used to their best advantage and are stored correctly so that the livestock have an adequate supply throughout the year. Since crop residues in themselves do not constitute an adequate ration for production or for young stock, complementation by high quality green fodder, and sometimes concentrates, must usually be foreseen.

The ease of harvesting and drying residues depends, of course, on the climate. In sub-humid and drier climates and in temperate regions there are usually few problems with straw harvesting. In the humid tropics and subtropics, however, the weather at harvest time may be such that it is difficult, if not impossible, to conserve straw, and especially legume haulms, in good condition. Groundnut tops harvested under hot dry conditions, for example, are an excellent feed, but where the harvest is under moister conditions the tops usually become a blackened, diseased mass before they can be dried. The proper drying of rice straw during the rainy season and on wet land is difficult, if not impossible, especially when there are many other demands on labour.

Stubbles are frequently grazed once the crop is removed, They often contain, in addition to the bases of the cereals and some straw, valuable feed in the form of grain which has been lost in the harvesting process, especially after mechanical harvesting, and weeds. Some methods of grain harvesting leave the plant standing after the heads or cobs have been removed by hand; this is common with small-scale farm systems for rice, maize, bulrush millet, finger millet and sorghum. Where feed is plentiful or where labour is scarce, these residues may be grazed *in situ*. This is advantageous for the livestock at the time, in that it allows them to graze selectively and probably find at least a maintenance diet from what might be a sub-maintenance feed if taken as a whole. It does, however, lead to a lot of wastage through trampling. Where there is an overall shortage of roughage for the dry season or winter it is preferable to harvest, dry and store as much of the crop residues as are necessary to assure the farm's roughage needs through the lean season.

Traditional ways of organizing grazing of crop residues may develop where specialized agricultural and stock-rearing communities are in the same area, such as the interaction of the Fulani herds in West Africa with several settled agricultural groups. Stubble grazing rights may be given to the herders (with or without payment) to the mutual benefit of both communities: the livestock eat the stover and also recycle fertility to the arable land; the herds are often kraaled on specified fields at night to build up their fertility. Recently, especially in drought periods, however, there has been a move towards harvesting the stover and selling it to passing herds.

In North Africa, transhumant flock-masters (who graze their herds from the desert fringe to the more northerly agricultural lands, according to season) buy stubble and fallow grazing in the crop-producing, higher rainfall areas to feed their herds through spring and summer. The shepherds are skilled in estimating the amount of grazeable forage on any given piece of land and in finding a succession of fields to see them through the season.

Crop residues in soil conservation

The great role of stubble in protecting soil against both hydraulic and aeolian erosion is well known. Stubble-mulching allied to minimum tillage is a well-established technique for protecting soil and conserving moisture in large-scale farming in cold semi-arid regions. Stover left on the field will also protect the soil, and cutting crops like maize and sorghum well above soil level can provide useful protection to the soil. In small-scale farm systems, however, straw and stover are often so greatly sought after as feed, thatch, bedding and fuel that crops are frequently cut to ground level, and maize roots may be dug out and dried as fuel.

Competing uses

Straws, stovers and chaff have many uses other than as animal feed within the farm economy, and these must be taken into account when assessing availability and profitability in livestock feeding systems. Within livestock production systems, straw is also used as litter and bedding (providing farmyard manure or compost), and chopped wheat straw is locally much in demand as poultry litter. Straw, especially rice straw, is often purchased by paper factories; straw is also widely sold for use as packing materials; straw and rice husk is widely used in semi-artisanal brick manufacture; chopped straw mixed with mud is used for plastering, both internally and (in hot, dry climates) externally; the strong stems of maize, sorghum and bulrush millet are used in traditional building, screens and grain stores; long straw is used as thatch; and straws and stovers are used as fuel in areas of scarcity, alone or chopped and mixed into dung cakes.

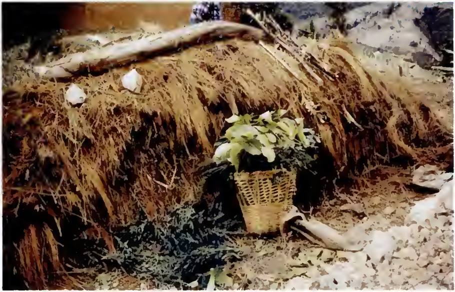
STRAW

The proportion of straw, or stover, to grain varies from crop to crop and according to yield level (very low grain yields have a higher proportion of straw - the ratio is infinite when a crop fails through drought) but is usually slightly over half the harvestable biomass. The height of cutting will also affect how much stubble is left in the field: many combine-harvested crops are cut high; crops on small-scale farms where straw is scarce may be cut at ground level by sickle or uprooted by hand, as is common on the Loess Plateau.

Rice straw

This is one of the most important cereals in the world, and especially so in Asia. Much is grown under small-scale farm conditions, with the straw widely used as a feed for work and milch stock. Methods of harvest vary. Often, in small-scale farm systems, either the heads or the whole crop is cut by sickle; frequently the crop will be cut while still in standing water because of the weather or lack of water control. The grain is then threshed out by beating on a rack or stone, or by using a small thresher. Mechanized rice production is usual in areas where combine-harvesters can be used. Rice straw is unusual in that the stem is more digestible than the leaves, the opposite of other cereals. For livestock feeding, it is therefore advantageous to cut it as close to the ground as possible. With hand harvesting, the crop is often cut when the straw is still relatively green. This will produce a higher quality straw for feeding than from mature plants. When only the heads are harvested the straw should be cut as soon as possible after the heads are removed (if labour is available), and dried to conserve its quality as a feed.

Figure 36. Rice straw stacked by a homestead in Nepal; the tree leaves are supplementary green feed



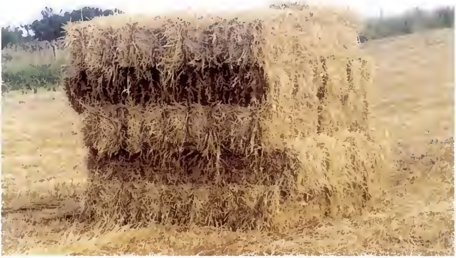
Drying rice straw is often a problem in high-rainfall areas because double-cropping means that at least one harvest is under very wet conditions. With the pressure of work at threshing time, it is difficult to ensure adequate care in spreading out the threshed straw to dry, and so a poor, mouldy product is often the result. Wherever possible, rice straw should be dried (on bunds and dry areas) as soon as possible after threshing in order to ensure the best possible straw for livestock feed. In high rainfall and flooded areas, such as parts of Bangladesh, straw drying is almost impossible during the rainy season. Where drying is very difficult, the feasibility of using urea or ammonia treatment as a preservative, as well as a means of improving digestibility and intake, should be studied.

Rice straw is regularly fed to ruminants throughout the rice-growing countries. It is often the main food of mature draught stock (cattle and buffaloes) over most of the year and they seem to work and survive on it despite its low digestibility and protein content. It is often fed *ad libitum* and sometimes grazed. This gives the animals the opportunity for some selection of the parts they consume. In those rice-growing countries where milk is traditionally consumed, rice straw is also fed to dairy cattle, and more especially buffaloes, but with supplements of green fodder and concentrates. Rice straw and husks have many uses other than animal feed and are traditionally used in brick-kilns, as packing material, and for paper-making.

White straws

The straws of the common temperate cereals have long been fed to livestock and are still very important in developing countries. Developments in harvesting methods may have affected straw quality in some parts of the world, and in the temperate zone especially. The traditional method was to mow the crop before it was in danger of shattering, then bind it into sheaves (originally cut by scythe or sickle and hand-bound; later mechanized by the reaper-binder), where the ripening and drying of the grain was completed before threshing, which might take place much later, with the crop stored in stacks in the interim. More modern methods, and especially the introduction of combine harvesters and grain drying, usually mean that the crop is cut at a slightly more mature stage than was the case previously, with more leaf loss and straw of lower feeding value. Modern clean-weeding by herbicides has greatly reduced the grasses and other edible herbage which, formerly, was mixed with the lower part of the straw.

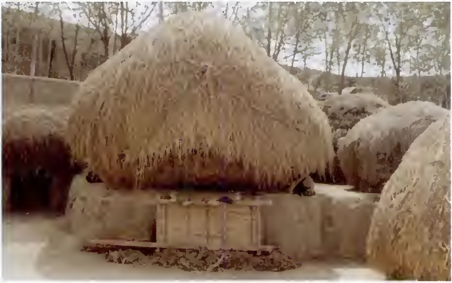
Figure 37. Standard bales of barley straw grouped for field-drying and transport (Dunecht, Scotland)



Farmers' opinions differ greatly, from country to country, as to the feeding value of wheat straw. In western Europe it is considered very poor, and not fed except in emergency (oat and barley straw were the only ones recommended as feed in UK until modern straw-treatment techniques were introduced), but now it is used after ammonia treatment. In the traditional wheat-growing countries of Asia and North Africa, however, wheat straw is highly prized and great care is taken in collecting and storing it. The form of straw depends on the threshing method. Where threshing was by flail, long straw is produced, and modern threshers give the same result. Where threshing was through treading by animals or with a ridged roller, the straw is broken into pieces 5 - 10 cm long (*tibn*, *bhusa*) and this system was very widespread in North Africa and Asia. Treading has now often been replaced by threshers; those used in India and Pakistan are constructed to chaff the straw during threshing. Chaffed straw is often stored in tightly-packed stacks, mud-plastered to protect them from rain and livestock. Mud covering can also be used to seal stacks for urea treatment.

Oat straw is a good and palatable roughage, as is barley. These straws are easily collected, handled and baled in mechanized systems with ordinary haymaking equipment.

Figure 38. Straw of foxtail millet (*Setaria italica*) in carefully built and thatched stacks (Gansu, China)



Straw of small millets

The straw of foxtail millet (*Setaria italica*), which is an important crop in northwestern China, is well accepted by livestock. Finger millet (*Eleusine coracana*) straw is considered a good feed in India and Nepal; the heads ripen unevenly and are hand-harvested in stages; the straw is cut and dried thereafter. The straw of common millet (*Panicum miliaceum*) is hairy and its palatability mediocre.

STOVER

The residues of maize, sorghum and millets are major forages in developing countries, and maize stover is also widely used in commercial agriculture. In small-scale farm systems, stover is usually handled and dried in the long, unchopped state, often by stooking in, or on the boundary of, the field prior to storage. In large-scale systems it may be baled, but can also be collected by forage-harvester and ensiled with or without urea treatment.

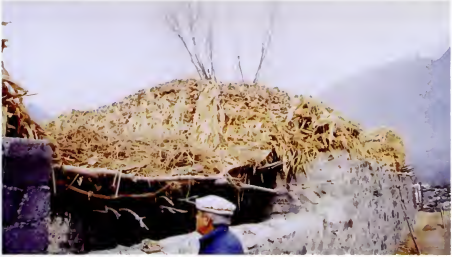
Maize Stover

Maize is the best of the cereal stovers for livestock feed. Where very abundant in relation to the livestock, it can be grazed off; otherwise, on large enterprises, it can be ensiled or collected and dried. Many small-scale farm systems collect the stover when the cobs have been harvested and either dry it in the field or at the homestead. In some places of fuel scarcity, even the roots are dug up together with the stem bases and used as fuel. Cut stover can be ensiled if chopped, moistened, well compacted and sealed.

Maize stover has a higher nutrient content than most straws, with about 6% CP. In North America, it is frequently fed to dry, pregnant cattle as basis of their ration; either grazed or chopped, and fed with or without being ensiled. It is often stored by stacking or baling after field drying.

Sweet-corn cobs, now a widely-grown commercial vegetable for fresh use, canning and freezing, are harvested while the plant is still green, and thus provide a large yield of high-quality roughage as a by-product. Sweet-corn stover benefits from being left growing a few days after harvest of the cobs. Maize is often harvested as roasting cobs, for sale in urban areas; as it is at a more mature stage than sweet-corn, the stover from such plants is a superior feed (or if dried, hay) compared to that from a fully-mature crop.

Figure 39. Roof-top storage of straw and stover - it also helps keep the animals warm (Gilgit, Pakistan)



Sorghum stover

This is a valued feed, especially if cut and dried immediately after the heads have been harvested for grain. Frequently, the heads are hand-harvested as they ripen and the stover harvested separately, preferably by cutting as green as possible after seed harvest and field drying in the same way as sorghum hay. Grazing *in situ* is done in some countries, but it is potentially dangerous because of the likelihood of cyanogenic substances in any re-growth, and also wasteful, as is always the case with grazing of stover. The stems of tall, robust varieties are used for fencing, building grain cribs and other light construction work.

Bulrush millet

A coarse, poor feed, usually reputed to be of low palatability; it is nevertheless popular in parts of India. Under small-scale farm conditions, the heads are hand-harvested and the stover cut once grain harvest is complete.

Residues of pulse crops

Many of these have a higher feeding value than cereal straws, but are much more difficult to recover; in humid climates the leaves tend to discolour or drop at or before harvest, and in dry conditions they shatter. Where the final drying of the crop takes place at the homestead, it is easier to recover the leaves and stems. The leaves and stems of other commonly grown pulses, but not described below, are many of them also useful feeds, such as the various *Phaseolus* spp., green and black grams, and the leafy parts of pigeonpea. Fava beans, however, have coarse, woody stems, while the straw of chick-pea (*Cicer arietinum*) has a very high oxalic acid content, is unpalatable, and reputed to be toxic.

Groundnut tops as "hay"

In areas where good drying weather occurs at harvest time, very useful hay can be produced from groundnut haulm. Groundnuts should be dug when the leaves begin to change colour to a yellowish shade and the haulms begin to dry. Sever the tap root and dig up the nuts then windrow and dry the foliage. The partly dried haulms may be stacked in small heaps. In the drier parts of Asia, groundnut tops are carefully harvested and then dried at the homestead, on house roofs and other sunny places protected from livestock. They may also be stacked on stakes, dried for 3 to 6 weeks and then threshed: the straw from this method is useful, despite its appearance.

Pea haulms

Green vines from canning, fresh and freezing crops are a valuable by-product and are best conserved as silage. The frozen pea crop is a large one, mainly grown in developed countries. Pease straw, from fully mature plants for dried pea production, is a useful roughage.

Soybean haulms

The haulms from hand harvested crops when properly cured are a useful feed. Successful harvesting is, however, very dependent on suitable weather and often the leaves are diseased or senescent by harvest time.

Cowpea haulms

These are an excellent fodder and are carefully stored in countries where the climate at harvest time is suited to drying. They are traditionally used in sheep-fattening in the Sahelian zone.

TRADITIONAL STORAGE AND UTILIZATION SYSTEMS

Storage systems have evolved with the many crops and livestock production systems associated with crop residues. Often they are similar to those used for hay and described in Chapter III. The methods of storing white straws depend on the threshing system (i.e., whether long straw or chaffed). Long straw is often stacked and thatched, or small quantities are stored on house-roofs, in lofts and outbuildings. Tree storage is also used, to keep it above the reach of livestock. Stacking should be on dry foundations of stone or brushwood. Chaffed straw is mainly produced in semi-arid areas; tightly packed stacks or heaps protected with mud plaster are a common system for storing large quantities. These may be in a corner of the field, on waste land or near the eventual point of use. In dry areas, such stacks are made directly on the soil.

Rice straw is always long (and almost impossible to chaff). The care taken in its storage and conservation varies greatly from place to place. Usually it is roughly heaped, either on field edges or where livestock are kept or gathered at night. Often, the stock are allowed direct access to the stack and eat selectively. It should preferably be fed in addition to other feed. Where there is an overall scarcity of roughage, however, rice straw is stored with more care and may be put in the crotches of trees, or in stacks protected from stock. Cattle shelters with the straw stacked on the flat roof are used in some areas.

Stovers are still grazed in some countries, especially in parts of Africa; this is wasteful but does save a lot on labour and returns some dung to the fields. Where dried roughage is highly valued and there is a dry season after harvest, stovers are usually dried in sheaves, and in dry areas are often stored by stacking the sheaves together with the stems more or less vertical.

BETTER HARVESTING AND STORING

Production of more and better conserved straw for livestock feed could be attained in several ways. Dual-purpose varieties of cereals - where straw quantity and quality are taken into account in addition to simple grain yield- are one approach, but their extension will depend very much on the economics of straw and livestock *vis à vis* grain, as well as the grain quality of such varieties when grown for subsistence. The general trend in cereal variety development has been towards shorter growing cultivars with less straw; the "stay green" quality of some maize cultivars, however, not only helps increase their grain yield but also provides a better stover for animal feed.

Improvements can be made to straw yield (or recovery) and quality, without changing cultivars, by attention to agronomic details at the time of harvest and immediately afterwards. Where the whole crop is cut at harvest, the straw should be dried as quickly and thoroughly as possible, and stored with care. Where heads or cobs are hand-gathered, the cutting and drying of the stover or straw should be done immediately grain harvest is completed, with the fields protected from grazing livestock in the period between grain harvest and straw collection. Stooking of maize and sorghum allows final ripening of the grain after the plant is cut; this provides stover of better feeding value than if the crop is allowed to mature standing. Topps and Oliver (1993) give some analyses from Zimbabwe (Table 7). As with hay, careful carting and storage (with or without baling) are very important.

Table 7. Effect of stooking maize on stover composition

Stage of cutting	TDN (%)	Protein (%)	Digestible protein (%)
Stooked	45	4.0	1.0
Late-cut	40	3.0	2.0

Field handling and baling

The mechanized handling of the straw of small cereals is similar to that of hay, as described in Chapter II. Since straw is from the mature and relatively dry plant, and much less leafy, it is much easier to cure than green herbage. Windrowing followed by pick-up baling can often be done soon after the combine-harvester has passed. Straw to be transported off the farm is often made into high-density bales - over 200 kg/m^3.

In small-scale farm systems, the crop is usually taken to a central point for threshing (which may or may not be on the field). The straw will therefore have to be taken from the threshing area for final drying, if not already dry enough (especially likely in the case of rice). With some crops and harvesting systems, most of the straw may be left in the field after the heads are harvested; e.g., rice in some systems, and finger millet: such straw should be harvested and dried as quickly as circumstances allow. Small-scale farms usually store straw un-baled, long or chaffed according to the crop and threshing system.

STRAW TREATMENT

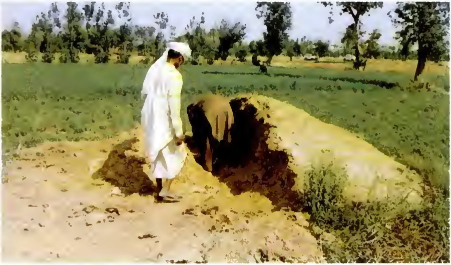
Straw treatment improves both quality and conservation. When straw is treated with an alkali, the ester linkages between lignin and the cell-wall cellulose, polysaccharides and hemicelluloses are hydrolysed, thus causing the carbohydrates to become more available to the micro-organisms in the rumen. Sodium hydroxide was used but has problems of cost and handling. Anhydrous ammonia or a solution of ammonia in water is now used. Gaseous ammonia is best suited to large operations and can only be used where the distribution system for ammonia (tankers, cylinders) is available. It has the great advantage that the straw can be treated in the bale when baled material is being treated. Ammonia acts as a fungicide (the process also creates anaerobic conditions) while also increasing crude protein content. Treatment requires airtight conditions.

For small-scale farms, it is generally more convenient to generate ammonia from urea, a widely-available fertilizer which is familiar to most farmers, by the "wet ensiling process". Ammonia is produced from urea, which is broken down by the action of urease ($NH_2\text{-}CO\text{-}NH_2 + H_2O \rightarrow 2NH_3 + CO_2$), through bacterial action, when it is mixed with moist straw; the process is rapid at high temperatures and so is suited to subtropical and tropical conditions rather than to temperate climates or subtropical winters.

The following description of straw treatment with urea is from the FAO (1993) publication *Tropical Feeds*:

> "Of the chemical treatments available, urea treatment has the most relevance to small farmers. Urea is added to the straw at the rate of 5% w/w (air-dry basis). The quantity of water may range from 0.3-1 l/kg of air-dry straw, with a minimum being applied in areas with water scarcity. If the straw is wet with rain or with freshly harvested straw containing much green material, urea can be applied without prior dissolution.

Figure 40. Urea-treated straw being taken from a mud-cased heap. Note the berseem behind (Punjab, Pakistan)



"Straw can be kept in various ways during treatment. Airtight conditions produce the best results. The conventional method is to use plastic sheet. A concrete silo, above ground and lined with plastic, will invariably produce good results, but concrete and bricks can be costly and difficult to obtain in some circumstances. A construction of earth bricks (clay mixed with straw), as used for making houses or storing grain in parts of Africa, is also suitable. Oil-drums or plastic bags can be used for very small-scale (single animal) quantities. Alternatives can be worked out locally: in dry areas, they can be below-ground pits lined with straw, banana leaves, or bamboo leaves or mats; in wetter areas, they can be stacks against a wall or fine-mesh wire (chicken wire) containers. When straw is stacked against firm structures (walls, pits, meshed wire), trampling can be done to compact the material and wet straw will not allow air to enter. Even if 100% airtight conditions are not achieved, good results can still be obtained and the outer (untreated) parts can be fed to animals with lower requirements, such as draught bullocks or dry cows, while the inner part is fed to growing and lactating animals.

"Treatment time may vary from 1 - 4 weeks. In intensive work undertaken in Bangladesh and Sri-Lanka in the early 1980s, 7 - 10 days was normal, with no benefits in animal performance obtained by longer treatment. However, temperature and treatment time are inversely correlated and more time is required in winter or in colder climates. In well-compacted straw, the temperature rises over 10°C after one week."

A detailed description of small-scale farm processing of straw with urea is given by Dolberg in FAO's *Better Farming Series* (FAO, 1995c), and gives the differences between treated and untreated straw shown in Table 8.

Table 8. Expected effect of straw treatments

Untreated straw	Treated Straw
Poor-quality feed	Reasonable-quality feed
Unpalatable, so animals eat little	Palatable, so animals eat more
Animals lose weight	Animals gain weight
	Animals produce some milk

The signs of successful treatment are given as:

- ➢ The straw has changed colour to dark yellow or brown.
- ➢ The straw has a strong ammonia smell.

- ➢ The straw is softer than untreated straw.
- ➢ The animals, after a period of adapting, eat one-third more than untreated straw.

The equipment needed for simple, small-scale treatment is a means of weighing straw (usually several standard bundles or baskets would be weighed and volume measures used thereafter); a volume measure for the standard quantity of urea used; a ten-litre bucket and a large water reservoir; the concentration used is 5%, or half a kilogram in 5 litres of water for every 10 kg of straw treated. Whereas straws need not be chopped before treatment, stovers must be, unless they can be very well compacted.

Urea treatment should be timed to fit in with crop-harvesting operations and wherever possible done before the straw or stover has already been stored or stacked, to avoid double handling and extra labour. This will also help ensure that the straw is in good condition; dirty, mouldy or rotten straw must never be treated as the result would make a poor and potentially dangerous feed.

Straw in standard and big bales is suitable for ammonia treatment as the ammonia gas can diffuse through the straw without pre-mixing or opening of bales. Many farms now use anhydrous ammonia as fertilizer. Some of the ammonia reacts with the straw to provide some nitrogen available to the rumen microflora. Anhydrous ammonia or a 35% aqueous solution are used. The straw must be completely sealed - usually under plastic sheet. Standard bales are stacked 50 x 4 or 5 bales wide, in stacks of about 30 t on a plastic sheet; the top is slightly ridged to shed water; the whole is covered with another plastic sheet which is sealed by weighting. The sheet may be roped or netted as protection against wind. Ammonia is injected through holes in the sheet, which are immediately sealed with a special seal. Big bales can be stacked, but care is necessary; they are usually put in plastic sleeves, singly or in groups, and injected. The site for storing treated big bales must be carefully chosen to ensure drainage, and access at the time when they are to be used.

OTHER FIELD CROPS

Sugar cane

The tops of sugar cane, the terminal leaves, the bundle sheath and one or more nodes are a valuable feed. The point of cutting depends on the millers' requirements, but is usually at the highest fully-formed node. Quantities vary with cultivar, management practice and growing conditions, but is of the order of

18% of the aerial biomass and a reasonable crop can, therefore, provide 5 t/ha of dry matter. Where cane cutting is seasonal, livestock often depend on cane tops during the winter harvesting season when other feed is scarce. For example, in the sugar growing areas of the Indo-Gangetic plain, canes are often a welcome source of roughage at the end of winter. The tops are readily accepted by livestock, but are low in protein and require supplementation. Where animals can graze them selectively or if the dry leaves are removed, their feeding value is improved. Cane tops can be conserved as silage. Sugar cane can be grown as a fodder and is unusual in grasses in that it has its highest energy content at maturity. It can be chaffed and fed direct, or ensiled; cane can also be fractionated using simple crushers, so that the juice is used for monogastrics and the residue for ruminant feed.

The wastes from processing - bagasse and molasses - are also useful feed sources, especially the latter, which is high in readily available energy, but these are agro-industrial by-products. Bagasse is also used as fuel and in the manufacture of particle-board. The residues of artisanal cane-crushers has much more sugar left in it than factory bagasse and is a much more useful feed in consequence.

Sunflower heads

The threshed heads of sunflower, provided that they have been dried before threshing (this depends on the climate), are a valuable feed. In the Trans-Nzoia area of Kenya, where sunflower is grown for bird-seed, the crop is harvested by cutting the stem at waist height with a sloping cut when the seeds are fully formed, cutting off the seed-head and spiking it, seed-side down, on the cut stem to dry and avoid bird damage. The heads are further sun dried before threshing. The threshed heads, which may contain some seed, are then put through a coarse hammer mill before being added to ruminant feeds. The crude protein content of the heads is 7 - 9%. Once dried, they can be stored for long periods. With the tall, grey-striped cultivar in a reasonable crop (2 t/ha), the ratio of seed-head to seed was around 1.2. The stems are poor feed and are usually either ploughed in or used as fuel. In Zimbabwe, heads are sometimes dried once the seed has formed and then ground, without threshing, as feed. Topps and Oliver (1993) give the crude protein content of the resulting meal as 14% and the crude fibre as 25%.

Cotton sticks

The leaves, twigs and unripe bolls of cotton are eagerly browsed by small ruminants after harvest and are a good feed, but only if the insecticide regime of the crop has been a suitable one! Sticks can be dried for winter feed, with the thicker stems used as fuel.

Miscellaneous moist residues

Not all crop residues suitable for livestock are dry. Many fresh residues are locally important as feed sources. Sugar beet tops are a good feed, but are conserved by ensiling, not drying (the pulp - a very valuable feed - is an agro-industrial by-product). Horticultural crops produce large quantities of herbage which, while not consumed by humans, is nevertheless useful animal feed and used opportunistically. The unsaleable parts of brassicas (and a hectare of cauliflower can yield a lot) are usually only suitable for feeding fresh. Sweet potato tops are an excellent feed, equivalent to good legumes. Yam peelings are traditionally fed to backyard sheep and goats in the yam belt of West Africa. Banana pseudo-stems are useful roughage, widely used as cattle feed - they are not suitable for drying, but can be ensiled. Some tree prunings are useful feed, especially for small ruminants, but they are usually available only sporadically and browsed on the spot, and often the bark is eaten as well as the leaves (e.g., mulberry poles in the Himalayan region).

Where tree prunings are available on a large scale, the leaves may be conserved for local use. The olive, which is cultivated on large areas in the Mediterranean zone of Europe and North Africa, and now also grown commercially in the Americas, provides large quantities of twigs and leaves at pruning. These are highly palatable to livestock. It is preferable to feed the leaves green, but they may be dried for later use or stripped off the branches and ensiled. Undergrade fruit and some wastes from fruit and vegetable processing (citrus marc, pineapple waste, pea haulms) are conserved as silage.

CHAPTER X

USING HAY AND DRY RESIDUES

Once hay or crop residues have been stored they should be used as carefully and economically as possible. Therefore proper care should be taken: during storage and handling to avoid spoilage and loss; in feeding techniques and livestock management to avoid wastage; and in ensuring that they are used in the context of a balanced feeding system.

If stock are to make the best use of feed, they must be healthy and correctly handled. Apart from routine control of epizootic diseases, internal and external parasites may also have to be dealt with. Such treatments are costly, however, and, unless they are part of local practice, advice should be sought before using them routinely. Housing and shelter are required in some climates to protect livestock against cold, rain or sunshine.

Where hay is grown for sale, there is a choice between selling immediately - even direct from the field - or storing in the hope of high prices later in the year. The choice will depend on local circumstances and farm cash-flow. The case studies from Turkey and India show that hay production for sale is not limited to large-scale farms: small-scale farms make hay, often from natural pasture, for sale to urban and peri-urban areas, even when their own stock have to subsist on straw. Straw is often sold, loose or baled, direct off the field. In India and Pakistan, it is bought for milch and draught stock in towns.

Storage of hay and residues is discussed in Chapters II and IX. Once in store, they must be kept dry and protected from stock, damp and fire. This may require further thatching or covering of stacks (where hay is stored loose) and keeping the storage area clear of loose material. In traditional systems, stacked hay is usually taken from the stack to a barn or store before distribution to stock. If the store cannot hold a whole stack, the remainder left outdoors must be protected from rain and wind by heavy plastic sheeting or a tarpaulin, otherwise the hay will be spoilt, weathered, and possibly blown away. Carting of loose hay and straw to livestock, housed or in the field, must also be done so as to avoid loss. Baled fodder is simpler to handle because the bales are practical units for distribution.

Hay and residues in feeding systems

Hay is a roughage, and is usually far from a complete feed. Even from high-potential crops with modern machinery, the resultant hay is often inadequate to provide a production diet for cattle. The poor nutritive quality of tropical grasses, and therefore of hay from them, was discussed earlier. High quality legume hays made in dry warm climates are usually of high feeding value, but grass hays in more humid climates and from tropical herbage are of lower quality. Straws and stovers are, of course, much poorer feeds than good hay. It follows, therefore, that these dried fodders should be part of a feeding system rather than used alone.

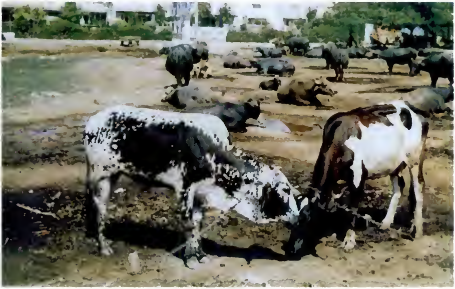
Some analyses of hays and residues are given in tables at the end of this chapter. These make it quite clear that most tropical, and many other, hays, and almost all residues, will always require supplementation when used in production rations. Many would also require it for maintenance. Only some legume hays can provide enough protein to supplement other roughages.

In stall-fed production systems, as in dairying and fattening, the role of hay and straw is relatively simple: they provide bulk in the ration and, according to quality, some energy and protein, but will usually be supplemented with concentrates and, in season, green fodder. Mature work oxen can subsist on very coarse roughages, although they may need some concentrates during hard work. Growing and milking animals are a very different case, as their needs for protein and minerals are high (and in proportion to growth or the milk yield). How the formulation of a ration should be arrived at will be found in the standard textbooks on livestock feeding; it is the overall composition of the ration that matters, and the components are complementary.

Feeding methods

Poor feeding techniques are a common source of wastage: hay is often fed in the field by simply distributing it on the ground, and this can lead to heavy wastage through trampling and contamination. In some situations, feeding on the ground may be unavoidable, but racks should be used wherever possible. Hard standings help avoid contamination, but are expensive. Hay and straw are often fed to overwintering stock for maintenance, so bales are distributed in the field, leading to waste and treading. When dry fodder has to be fed loose in the field, waste will be less if it is distributed little by little so that the stock eat it all and wait for more.

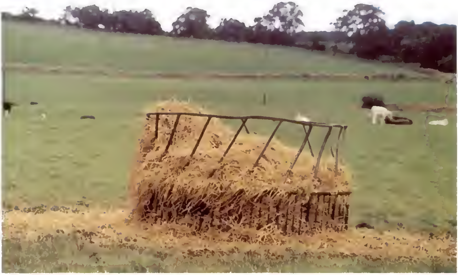
Figure 41. Urban dairy stock which are fed, year-round, on crop residues, green fodder from the hinterland, and concentrates (Lahore, Pakistan)



Long hay and straw should be fed from racks or mangers to reduce wastage and the racks should be designed for the type of animal to be fed. In arid areas, troughs are often built from mud; elsewhere wood, metal or masonry are used. Where buffalo are being fed, troughs must be particularly robust, otherwise the stock will smash them. A lot of wastage from racks and troughs can be avoided if they are lined or covered with weld-mesh to restrict the amount which animals can pull out at one time. The selective feeding habits of sheep are a problem, but mesh over the trough helps. Portable racks, on wheels, are used for field feeding, and should be sited either on hard standing or on a well-drained part of the field, and shifted regularly to reduce damage to the sward.

Standard bales must be opened for feeding. Those made by a slicing-ram baler come apart easily in slices, thus facilitating distribution. Particular care should be taken with wire-tied bales, now rare, to ensure that no pieces of wire (especially short bits) are left in the feed or around the feeding area since, if ingested, they may cause serious illness or death. Big bales are fed from frames made to hold one bale exactly - the bale is placed by front-end loader, the outer covering cut and it is ready to eat (See Figure 42).

Figure 42. Big bales being fed from special frames (Alford, Scotland)



For housed stock, the racks are often fitted above the trough or manger so that any feed which falls from the rack is held in the trough. All stall-fed stock, and here are included stock tethered at the homestead in the open where the climate does not necessitate housing, should receive their feed and fodder in troughs and racks. Feeding off the ground, apart from being wasteful, is a health hazard. Simple feeding systems can be made from locally available materials: wood, brick and stone - or even dried mud in arid places - and are associated with the improvement and intensification of animal production everywhere. Where straw is plentiful, it may be fed *ad libitum* so that the stock can feed selectively; the rejected straw in such cases is added to the litter or bedding, so less care is necessary in preventing losses from the racks.

Grazing of straw and stover is wasteful where there is an overall scarcity of roughage. When crop residues are in excess of the farm's needs, however, grazing does have the advantages that the stock can feed selectively and costs are low; the disadvantages are trampling and wastage. The leaves are more palatable and have a higher digestibility than the stems (except for rice, where they are similar); grazing stock will generally eat the more digestible leaves and leave the stems. With small cereals, sheep and goats are particularly adept at grazing selectively; large ruminants can graze coarse stovers and sugar cane tops selectively, but have difficulty with straws.

Where the residues are removed from the field at harvest, as in intensive irrigated systems to allow field preparation for the succeeding crop, residues can be fed to stock elsewhere, allowing about twice the amount they might require, permitting them to select (and reject); in this system the residues are not chaffed. Coarse, rejected, residues need not be wasted, for they can thereafter be collected, urea treated and then fed to stock. Selective feeding on straw does not necessarily assure an adequate diet, although it is a considerable improvement on non-selective feeding, so, for productive stock, supplementation should be done as necessary.

SEASONAL PLANNING

Fodder conservation should always be done as part of an overall feeding plan for the agricultural year: storing forage during the peak of the production season in order to supply roughage when grazing is scarce or inaccessible to stock. In the planning process, all available feed sources, including cereals and purchased concentrates must, of course be taken into account, as should fluctuations in stock numbers due to breeding, sale and slaughter. The aim should be to conserve a little more than may be required during the year (unless sale is the main objective); a small carry-over can be useful and may serve as a buffer in a bad year but hay and straw deteriorate with time and are not really suitable as medium-term emergency reserves.

Water is essential in all feeding systems and must be in regular supply at all seasons; its availability may dictate the movements of stock at certain times of the year and must be taken into account during planning.

Severe winters at high latitudes mean that livestock must be fed indoors for long periods. Traditionally, large areas of grass were cut for hay in the humid temperate zone, despite only moderate climatic conditions for drying, and this is still common in mountain areas of Europe, where yields are now boosted by chemical fertilizer. In lowland arable areas, silage from sown pasture or cereals has tended to replace hay. Winter feeding of concentrates is common.

In the colder and drier parts of central and northern Asia, both winters and long dry periods limit the availability of green grazing, so hay is traditional. Cultivated fodder, which originated in this region, is widely saved as hay. Concentrate feeding is not limited to the large-scale sector: feeding of cereals in winter, often barley and maize, is common in the traditional pastoral systems of the colder, semi-arid parts of Asia.

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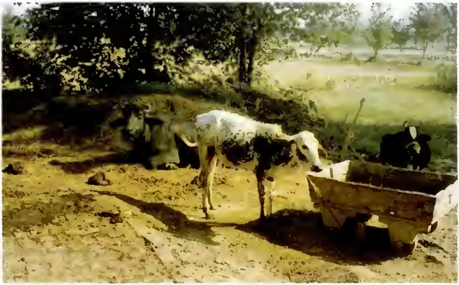
In a Mediterranean climate, the long, hot, dry, summer is a period of feed scarcity, but there may also be winter shortfalls in the colder areas. Late spring surpluses can be harvested as hay, which should be of higher quality than stand-over feed; oats and other sown fodders are grown for hay.

In the great irrigated zones of the subtropics, where mainly stall-fed cattle and buffaloes are very important, there are two marked periods of scarcity: the winter, mid-December to mid-February, and the very hot period of summer, usually late May to mid-July. At those seasons the stock have to rely mainly on straw and stover as roughage, without the usual admixture of green feed. Hay is a minor product despite the great quantity of sown fodder grown, although with the increased urbanization of the dairy industry, the production of dried fodder is increasing. In areas of severe feed scarcity, such as parts of the Himalayan foothills, the very poor hay made after the monsoon is highly sought after for want of other feed, and crop residues may be fed to stock which spend part of the day at "pasture," gleaning what herbage they can from degraded land. The effort put into hay collection and transport, often by porterage, shows that the dried grass is valued, but whether primarily for production or for dung as fuel and manure is unclear.

Figure 43. Buffalo tethered beside loose rice straw; heifer at trough for feeding of other fodders; more valuable fodder is given in the wheeled trough (Punjab, Pakistan)



Chaffing of fodder

Chaff-cutters of the flywheel type are widely used in Pakistan and India for both green feed and stover, and contribute greatly to economy in fodder use by reducing selectivity and permitting thick-stemmed material to be easily eaten. Flywheel cutters consist of a metal frame in which a flywheel with two knives mounted on it spins at speed, the forage is pushed through the wheel by a force feed; the knives, which are easily replaced, are adjustable for angle and must be regularly sharpened with a file or stone. These are sturdy machines, manufactured in large numbers, and simple to maintain and repair by local technicians. Chaffers can be powered by hand, by draught animals (often using the drives of old Persian wheels), by tractor or by electricity. They are used throughout the northern irrigated tracts and are also common in urban areas if cattle are kept. In towns, fodder-chaffing may be a specialized occupation or associated with the local fodder market. Straw in these areas is chaffed during threshing. Stovers are coarse and usually thick-stemmed; where mechanical collection is used, they will usually have been chopped by the pick-up mechanism.

Figure 44. A hand-operated press for baling natural hay (Gujarat, India)

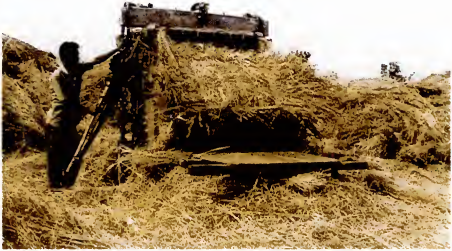


Photo: Ian Lane/C.S. Pandey

Figure 45. A farmer with lucerne hay in an area of extreme winter feed scarcity

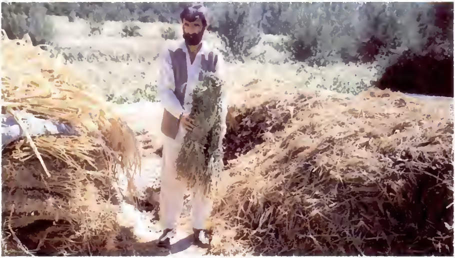


Photo: Dost Mohammad

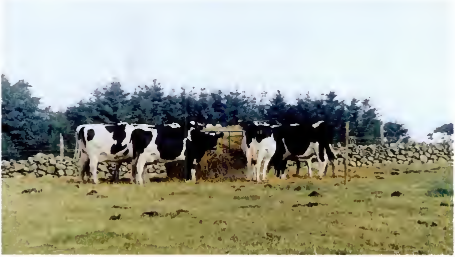
Hand-harvested material, however, is collected and stored long. In most situations it should be chopped or chaffed before feeding. In India and Pakistan, chaffed stover and straw are mixed with green feed and usually fed in troughs. Uneaten, coarse bits of chopped fodder may be added to dung cakes and so are used as fuel.

Hinged-knife choppers, worked by hand, are very simple machines which are still used in parts of China to chaff fodder and stover, as well as to reduce material for composting. However, although cheap and easy to manufacture, they are slow to use and require a lot of hand labour. Loose, partly chopped hay is ideal for mixing with other ration components and is much less prone to wastage.

Supplementation at pasture

In grazing and pastoral systems, the situation is less clear than for stall-fed production. Supplementary feeding is not additive to grazing. When hay, straw or concentrates fed to grazing stock replace part of the diet formerly grazed, because of substitution, the objective of utilizing pasture to its maximum and supplementing the animals with additional feed cannot be attained. The greater the supplementation, the less forage grazed. Where intake is limited by low availability of forage, the supplementation must take the place of forage.

Figure 46. Cattle being fed hay *ad libitum* while grazing rich pasture (Dunecht, Scotland)



Where, however, intake or absorption are adversely affected by a deficiency despite a surplus of forage, then a supplement acts as an additive to the diet (e.g., micronutrients, or protein in a deficient diet).

Supplementation may be at several levels and for different reasons: to assure survival, to assure maintenance, or to assure production and reproduction. It can be by providing complete feed or, at pasture, by giving specific nutrients to enable the livestock to consume more of a forage or to digest the same quantity of forage more efficiently, or to overcome a nutrient deficiency *per se*. Supplementation at pasture with hay or straw need not be because the pasture is poor: hay or straw are sometimes offered to grazing stock when the pasture is very lush, of high moisture or protein content or where there is a danger of bloat in legume-rich swards (Figure 46).

Where the climate allows stock to be outside throughout the year, survival strategies in the traditional sector are often based on allowing stock to lose some weight during the dry or cold season while foraging on what herbage is available, without supplementation. There is often a rapid regain of weight once herbage again becomes available. This gives an uneven or "stepped" weight gain pattern, and stock reach mature weights after several years, but costs and inputs are minimized. In cold climates, some hay may be fed to weak stock to help them survive. In tropical areas, hay is not traditional, but herds may have access to stovers. In some developing countries, especially in Africa, cattle may spend more energy on walking to feed and water than in commercial agriculture. Their grazing time is often restricted by being enclosed at night, since the grazing lands are unenclosed and there is danger of theft or of attack by wild animals. It may sometimes, therefore, be advantageous to offer straw and stover in the night-pen (*boma, kraal*).

Stock owners are well aware that distribution of hay (and other feeds) reduces foraging by stock, especially when herbage quality is low. When supplementation is fed while the stock are at pasture, it should, generally, be given once they have returned in the evening. An exception is where legume-based pastures are lush and there is danger of bloat; then dry fodder - be it hay or straw - should be given before they go out or, in the case of continuous grazing, be on offer in the field.

In cold semi-arid areas, cattle and yak herders prefer to let their stock graze frozen herbage rather than to feed hay, except to weak stock in order to save their lives and help them reach the following spring. A field visit to Arkhanghai Aimak in Mongolia (see case study) showed that herders are loath to give supplementary feed except to special classes of stock (milking and pregnant animals, saddle and pack horses) because fed animals tend to graze less and come home early to wait for feed. On the Qinghai-Tibet Plateau in China, Cai Li and Weiner report "A little hay is usually made but it is only given to sick or very weak animals (yaks) towards the end of winter" (FAO, 1995b).

Emergency feeding

In feeding for survival during severe drought or food scarcity, the principles are similar to those of stall feeding. Conserved fodder or silage can be used if available, but grain is usually more economical. Hay is usually made in the context of the normal feeding year (and production can rarely be increased ahead of a drought, even if the emergency can be foreseen). Hay reserves are difficult to store for long periods and the cost of transport of hay is high compared to that of more concentrated feeds. Therefore, while a hay bank may be prudent on a farm, when a real drought or emergency happens it is usually more economical to sell as many non-breeding stock as possible and use cereals and other concentrates to help the breeding stock to survive.

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Figure 47. Herders prefer to keep supplementary feeding of yaks to a minimum to encourage them to forage (Ikh Tamir, Mongolia)

Even good hay is relatively low in protein; tropical hay and crop residues will usually require additional protein if they are to be useful feeds. Protein supplementation may be in true form from concentrates (plant and animal) or from legumes in fodder banks. It can also be non-protein nitrogen, which can be used by rumen microflora; urea or ammonium bicarbonate are common commercial sources. Both forms of supplementation are most effective when the nitrogen content of the pasture is below that required for satisfactory microbial activity in the rumen and where a source of digestible energy is available. Less soluble "by-pass" proteins can increase intake of feed by ruminants - protein acts as a source of nitrogen and sulphur for rumen microflora, alters the flow rate of digesta and may supply an extra source of amino acids to the tissues. Its net effect is to increase intake of the green feed or concentrate.

Urea-molasses blocks are a source of both non-protein nitrogen and readily available energy: they were originally used to stop weight loss on poor pasture but are now much more widely used to supplement coarse roughages and in integrated feeding systems. The blocks can be made easily with simple hand tools if a cheap source of molasses is available locally, and should be considered wherever protein deficiency is a problem.

While protein is a major consideration at pasture, minerals, especially phosphorus, can be limiting and phosphorus is frequently below maintenance levels in poor hay and dry pasture. Mature, non milking stock in non-deficient areas may be able to pass the lean season on the reserves in their skeleton, but growing stock cannot. The phosphorus content of herbage (and the yield) can be raised by manuring, but phosphorus supplementation of the feed is usually the cheapest approach; sterile bone meal and some inorganic forms, such as di-ammonium phosphate and bi-calcium phosphate, can be used in concentrates or licks.

Feeding for production

Hay rarely provides a production ration on its own; straw and treated straw never do. In order to make full use of them, therefore, supplementation is needed. For moderate to high levels of milk production, oil-cakes, brans and cereal offals will be required. Growing cattle over a year old and work bullocks require only small quantities of supplements if the hay is reasonable or the straw treated. *Bos indicus* is probably more efficient in maintaining liveweight on low rations in time of shortage than *B. taurus*, and tropical work oxen (and buffaloes) often grow and work with little or no supplementation. In dry areas with open winters there is usually enough forage for stock to survive, but they lose weight over the dry season. In Australia, some supplement is desirable for stock grazing Mediterranean pastures in summer, tropical winter pasture or cereal stubbles. Grain can be used to maintain weight, or for production if desired.

FEEDING VALUES OF SOME DRIED FORAGES

Some analyses of hays and residues follow, but it should be kept in mind that while mature residues vary a little, the composition of forage that is mown green varies greatly according to the stage of growth of the plant, and the resulting hay will vary according to the climatic conditions at the time of its making and the skill with which it was cured.

Table 9. Analysis of grass hays (values expressed as a percentage of dry matter)

FEED	CP	CF	Ash	NFE	Ref.
Veldt hay, Zimbabwe	3.7	42.8	5.9	45.5	(1)
Avena sativa, Chile	7.1	30.9	4.9	55.2	(2)
Cenchrus ciliaris, early bloom, Tanzania	11.0	31.9	13.2	41.3	(2)
C. ciliaris, late bloom, Tanzania	7.4	35.2	11.7	44.0	(2)
Chloris gayana, 1St cut, Tanzania	3.7	43.5	8.7	42.8	(2)
C. gayana, 2nd cut, Tanzania	3.7	42.0	8.7	42.4	(2)
C. gayana, 10 weeks, Thailand	6.8	36.5	8.6	45.7	(2)
C. gayana, 12 weeks, Thailand	4.1	38.2	6.7	49.2	(2)
C. gayana hay, Zimbabwe	4.9	42.2	9.4	43.0	(1)
Cynodon aethiopicus, pre-bloom, India	6.4	35.6	6.8	50.6	(2)
C. dactylon, mid-flowering, Venezuela	10.4	27.9	9.9	48.8	(2)
Eragrostis curvula, stemmy, Kenya	6.3	34.5	5.5	5.4	(2)
E. tef, late vegetative, South Africa	10.5	34.2	5.3	48.9	(2)
E. tef, mature, South Africa	8.8	33.1	6.9	50.1	(2)
Hyparrhenia rufa, Brazil	6.5	35	17.9	38.3	(2)
Panicum coloratum, South Africa	9.0	36.7	7.9	43.6	(2)
P. maximum, 10 weeks, Thailand	6.6	35.5	13.2	42.9	(2)
Pennisetum americanum, South Africa	6.6	41.2	10.0	40.9	(2)
Setaria italica, South Africa	7.6	45.1	9.7	35.9	(2)
Sorghum bicolor, Sudan	4.2	32.1	7.9	55.0	(2)
S. sudanense, South Africa	7.3	35.7	8.9	46.1	(2)
Themeda triandra, Uganda (mean)	3.3	39.3	8.3	47.9	(2)
T. triandra, Kenya	4.4	40.4	10.3	43.3	(2)
Triticum aestivum, India	5.1	35.1	7.2	51.3	(2)

Key to columns: CP = crude protein; CF = crude fibre; NFE = nitrogen-free extract; Ref. = reference source. **Reference sources:** (1) Topps and Oliver, 1993. (2) *Tropical Feeds* (FAO, 1993).

Table 10. Feeding value of teff hay in South Africa (as % of DM, except DOM and ME)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Early Bloom(12)	9.4	1.8	30.4	53.6	5.3	59.29	9.15	61.00	-	-	-
Full bloom(12)	8.6	1.1	36.6	46.5	6.2	57.22	9.0	58.80	-	-	-
Good(12)	9.4	2.2	30.4	53.2	5.6	59.50	9.18	61.20	0.37	0.22	1.20
Average(12)	8.6	2.0	36.6	45.6	4.7	57.50	8.85	59.00	0.37	0.17	0.90
Early Bloom(13)	12.1	1.8	30.4	-	-	61.0	9.10	-	0.37	0.22	1.20
Full Bloom(13)	8.6	1.1	36.6	-	-	58.8	8.80	-	0.39	0.17	0.90

Key to columns: (1) = crude protein (CP); (2) = ether extract (EE); (3) = crude fibre (CF); (4) = nitrogen-free extract (NFE); (5) = digestible crude protein (DCP); (6) = digestible organic matter % (DOM); (7) = metabolizable energy (ME; Mj/Kg); (8) = total digestible nitrogen (TDN); (9) = Calcium (Ca); (10) = Phosphorus (P); (11) = potassium (K).

Sources: (12) Bredon, Stewart and Dugmore, 1987. (13) Department of Agriculture, 1995.

Table 11. Analysis of legume and other residues, expressed as percentage of dry matter

FEED	CP	CF	Ash	NFE	Ref.
Cowpea haulms, Nigeria	17.5	24.9	7.8	48.2	(2)
Groundnut haulms, South Africa	9.9	21.1	9.3	57.3	(2)
Guar vines, India	10.6	23.9	10.6	53.4	(2)
Sulla straw, Italy	5.8	51.8	7.5	34.6	(2)
Sunflower heads - whole	12 - 14	-	-	-	(1)
Sweet potato vines - dry forage	13.0	-	-	-	(1)

Key to columns: CP = Crude Protein; CF = Crude Fibre; NFE = nitrogen-free extract; Ref = reference source. **Reference sources:** (1) Topps and Oliver, 1993. (2) *Tropical Feeds* (FAO, 1993).

Table 12. Analysis of legume hays, expressed as a percentage of dry matter

FEED	CP	CF	Ash	NFE	Ref.
Alhagi sp., hay, Pakistan, whole plant	10.2	28.8	2.42	-	(3)
Alhagi sp., leaves & thorns, Pakistan	10.6				(3)
Arachis hypogaea, Chile	26.2	27.9	11.6	31.6	(2)
A. hypogaea, mature, Israel	12.8	29.0	8.5	47.8	(2)
A. hypogaea, Zimbabwe	11.1	27.9	19.1	38.7	(1)
Crotalaria juncea, Zimbabwe	13.9	30.8	9.9	30.8	(1)
Cyamopsis tetragonoloba, hay, India	25.2	13.8	16.5	43.6	(2)
Glycine max, with leaves, South Africa	13.9	35.5	5.5	42.6	(2)
G. max, few leaves, South Africa	19.5	23.9	10.6	53.4	(2)
G. max, Zimbabwe	13.4	31.4	7.5	44.5	(1)
Hedysarum coronarium, Italy	13.6	30.0	10.7	43.7	(2)
Lablab purpureus, Sudan	16.6	37.1	9.3	34.1	(2)
Lathyrus sativus, hay, Israel	18.2	30.5	11.1	36.9	(2)
Medicago sativa, early bloom, South Africa	17.0	38.2	8.7	33.6	(2)
M. sativa, mid bloom, South Africa	15.4	40.1	8.6	33.8	(2)
M. sativa, Pakistan	20.5	29.6	12.5	36.0	(3)
Trifolium alexandrinum, Pakistan	15.1	30.3	12.0	40.7	(3)
T. alexandrinum, Israel	16.6	26.2	11.1	43.7	(2)
T. alexandrinum, Israel	12.4	36.1	8.6	40.4	(2)
T. pratense, Chile	14.2	28.9	14.6	36.5	(2)
Vicia sativa, Israel	19.0	28.5		41.0	(2)
Vigna unguiculata, India	10.6	16.2	13.1	58.3	(2)
V. unguiculata, South Africa	14.4	22.5	9.9	51.1	(2)
V. unguiculata, Zimbabwe	18.2	30.8	7.1	42.4	(1)

Key to columns: CP = Crude Protein; CF = Crude Fibre; NFE = nitrogen-free extract; Ref. = reference source.

Reference sources: (1) Topps and Oliver, 1993. (2) *Tropical Feeds* (FAO, 1993). (3) Case studies in this publication.

Table 13. Analysis of some straws and stovers, expressed as a percentage of dry matter

FEED	CP	CF	Ash	NFE	Ref.
Barley straw, Kenya	6.0	39.6	9.3	44.5	(2)
Barley straw, Iraq	2.5	44.6	17.6	33.9	(2)
Bulrush millet stover, Pakistan	3.3	40.5	6.8	48.6	(3)
Bulrush millet stover, India	3.8	37.3	5.9	51.5	(2)
Bulrush millet stover, Tanzania	4.3	43.6	9.3	41.9	(2)
Finger millet straw, India	3.7	36.5	7.5	-	(3)
Maize stover, Zimbabwe	4.2	39.8	7.4	47.1	(1)
Maize stover, India	4.6	32.0	7.1	-	(2)
Oat straw, Kenya	5.3	38.0	10.2	45.1	(2)
Sorghum hay, Sudan	4.2	32.1	7.9	55.0	(2)
Sorghum stover, India	3.7	41.8	9.4	44.0	(2)
Wheat straw, India	3.5	-	7.5	-	(2)
Rice straw, India	4.0	37.0	18.0	-	(3)
Wheat straw, Zimbabwe	3.7	-	-	-	(1)
Cane tops, India	5.0	32.0	8.5	-	(3)
Cane tops, Mauritius	5.9	33.5	8.5	50.3	(2)
Cane tops, Zimbabwe	3.1	38.7	8.0	47.1	(1)

Key to columns: CP = Crude Protein; CF = Crude Fibre; NFE = nitrogen-free extract; Ref = reference source.

Reference sources: (1) Topps and Oliver, 1993. (2) *Tropical Feeds* (FAO, 1993). (3) Case studies in this publication.

TREATMENT OF CROP RESIDUES (AND POOR HAY)

The use of ammonia or urea to improve the digestibility of straw and supply some nitrogen has been mentioned in Chapter IX, as has its capacity to act as a conserving agent where proper drying is difficult. The same process can be used with low-quality bush hay. The type of treatment will depend on local circumstances. Ammonia treatment is suitable for large operations in areas where there is a supply of anhydrous ammonia and the necessary infrastructure of tankers to distribute it; it is also suitable for use in cool climates where the enzymatic breakdown of urea would be too slow.

Ammonia treatment is suitable for co-operative and village organization, especially where baled straw is used; this was clearly demonstrated with rice straw at village level in Egypt in the early 1980s (Creek, Barker and Hargus, 1984; Barker *et al.*, 1987). After testing and demonstration, a group straw treatment system was set up. Rice straw is the basis of ruminant feeding in many areas, wheat straw being scarce and very expensive. Farmers pooled their baled straw into large stacks, which were then treated with ammonia. Once treatment was complete the covers were removed and each participant could take his number of bales. Anhydrous ammonia is cheap and readily available locally, as are transport facilities; the climate is such that the treatment is rapid and so dry that, once treated, the straw does not need protection.

Animals should be introduced to eating treated straw over a week or ten days by introducing it gradually, mixed in more and more into the fodder that they are used to. Adaptation is quicker when animals are used to eating straw, and if the treated straw has been aired for some hours before being fed. As soon as the animals eat treated straw readily, it should be fed directly from the stack, not aired beforehand. Treated straw is more palatable and more digestible than untreated, so treatment automatically raises intake. This is, of course, the purpose of the process, but in situations where total dry matter supply is a constraint (which is unfortunately common in some areas), there is no point in treating if all that it will do is cause the supply to run out more quickly. This is debatable because of the improved nutritional value of the straw, but the treated product would have to be carefully rationed.

Dolberg (in FAO, 1995c) indicates that animals can be expected to consume one-third more treated than untreated straw, and recommends the following quantities:

Table 14. Untreated and treated straw feed quantities according to liveweight

Animal liveweight	Untreated straw	Treated straw
100 kg	2.0 - 2.5 kg	3.0 - 3.5 kg
200 kg	4.0 - 5.0 kg	6.0 - 7.0 kg
300 kg	6.0 - 7.5 kg	9.0 - 10.5 kg
400 kg	8.0 - 10.0 kg	12.0 - 14.0 kg

Treatment is recommended where straw constitutes over half the diet because better feeds are scarce, or where higher levels of production are aimed at. Farmers are often more interested in treating straw for stock which will give an immediate return, such as for milk or fattening.

CHAPTER XI
CASE STUDIES

Thirteen studies on traditional haymaking in small-scale farm or pastoral systems follow. Only the West African study deals with the introduction of haymaking as an innovation. They cover a wide range of existing practices and serve as background to the preceding chapters. There are studies from ten countries in Africa, Asia, western and southern Asia and Latin America. Some of the material has been contributed by national specialists; the rest is based on the author's experience during the many opportunities provided for travel on behalf of FAO.

Although the study areas are not claimed to be representative of all small-scale farm haymaking, some rough conclusions can nevertheless be drawn from them. Nine of the thirteen studies involve hay from natural herbage, but it is only a major component in six of them: Ethiopia, India, Mongolia, Nepal, Nicaragua and the Sahel. All excepting Mongolia are in tropical or monsoonal situations, with haymaking only feasible after the rains, when fodder quality is very low. The Mongolian site has too short a thermal growing season for sown fodder, and herbage quality at haymaking is satisfactory. Many sites for natural hay are on mountainous, marginal land; problems of access and rights to hay-cutting hinder improvement of their management.

Leguminous hay is produced in seven of the cases: Afghanistan, Argentina, the three Chinese sites, Pakistan and Turkey. In all it is the major hay source, and in five of the seven it is irrigated. All the legume-growing sites are in subtropical or winter-cold, semi-arid areas and, Argentina apart, are in Asia. Lucerne is the most widespread hay crop, with shaftal (*Trifolium resupinatum)* important in Afghanistan and Pakistan, while sainfoin (*Onobrychis viciifolia)* is mentioned from Turkey. No small-scale farm study reports grass being grown for conservation (although used on large-scale farms in similar climates). Oat hay is only important in Pakistan, although also grown on a large scale in North Africa.

Most of the fodder sown is from poor quality, home-saved, seed of local landraces. Low seed quality and non-availability of seed of better, locally-proven cultivars is frequently mentioned. The study from the Northern Areas of Pakistan demonstrates how the introduction of an adapted lucerne cultivar can have a big effect in an area where the traditional ecotypes are unsuited to the local climate.

Again in Pakistan, the introduction of multi-cut oat varieties changed the crop from a minor fodder to a major hay crop and source of cold-season green fodder.

Lack of maintenance fertilizer leading to yield decrease and poor persistence of lucerne stands is mentioned on several occasions. Poor hand-mowing techniques and timing of cuts, especially for lucerne, is also frequent. However, training in this may be complicated in many areas because much of this work is done by women and children. Competition with food crops for scarce land and water resources is a major constraint to the expansion of haymaking, and the need for a better lean-season feed supply is stressed in all studies, so the strategy will have to be increasing yields per unit area.

Mowing by hand is general, usually by sickle, sometimes by machete, and rarely by scythe. Only the Altai case reports use of mowers. There, the fodder area per family is quite large (4 ha) and most of the herders are on transhumance during harvest. Elsewhere hay is often cut, a little each day, and carried to the homestead for final drying. Much of the natural hay, especially on mountain sites, is from land where mowers could not be used. Rolling or tying hay into trusses or small bundles is widespread and is reported in seven cases, again all in Asia apart from Argentina. This is a traditional means of reducing leaf-loss in dry areas, both during curing and transport. Baling is rare and associated with long-distance transport; it is usually organized by merchants rather than by the producers.

Growing coarse cereals specifically for drying as fodder is reported from some tropical and subtropical areas with a well-marked dry season: India, Nepal, Nicaragua and Pakistan. Drought-affected crops may also be so used. Frequently, coarse cereal "hay" is grown where moisture would be inadequate to ripen a grain crop. Hand-harvesting methods for maize, millet and sorghum often allow the stover to be cut and dried at a much earlier stage than does mechanized harvesting, and so produces a higher quality feed

The use of straw and stover as feed is reported in all but one case (the Mongolian site cannot grow cereals), but the degree of care taken in harvest and storage varies. Straw treatment is not at all widespread, and is reported from Afghanistan and Pakistan only. Nine cases report that some of the hay and straw is sold. Sometimes, as in India, natural hay is harvested specifically for sale. Oat hay is now a cash crop in Pakistan. In other cases, hay is sold for ready cash and the farmers' own stock have to survive on straw.

CASE STUDY 1.
HAYMAKING IN ETHIOPIA

FARMERS' TRADITIONAL AND IMPROVED PRACTICES

Agriculture has always been, and remains, the cornerstone of the Ethiopian economy, and small-scale farming is the backbone of the sector. Small-scale production accounts for 96% of the cropped area and 90-94 % of the cereals, pulses and oilseeds produced. Agriculture employs 80-85% of the population. About 60% of agricultural output come from crops, with livestock and forestry producing 30% and 7%, respectively. According to the 1995/96 agriculture survey, cereals cover the largest share of the cropped land (84.55%), followed by pulses (11.13%) and others (4.32%).

Subsistence sector technology is largely traditional and rainfed, with very limited areas of irrigation. Cereal yields are 0.8-1.0 t/ha for teff, 1.2-1.4 t/ha for wheat, 1.1-1.5 t/ha for barley and 1.6-2.0 t/ha for maize, as estimated by the Central Statistical Authority. Livestock production is an integral part of the country's agricultural system. The various ecological zones allow the production of several species of livestock, which represent a major national resource. Ethiopia has the largest livestock population in Africa: 30 million head of cattle, 23 million sheep, 18 million goats, 7 million equines, 1 million camels and 53 million fowls. Cattle play the most important role in the farming economy, followed by sheep and goats.

Livestock production systems in Ethiopia are determined by climate, vegetation, the types of crop grown, livestock species reared, and their economic importance to the producer. In the highlands, livestock are subordinate but economically complementary to crop production, the main agricultural activity of the farmers. In this zone, livestock, especially cattle, provide traction, which is vital to the overall farm labour supply. Livestock also provide milk, meat, cash, manure and serve as a hedge against risk. In the semi-arid lowlands cattle, again, are the most important species because they provide milk for the subsistence of the pastoral family. In the more arid areas, however, goats and camels are the

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1. Based on material provided by *Alemayehu Mengistu*.

dominant species. The former provide milk, meat and cash, while the latter are kept by nomadic pastoralists for milk, transport, and, to a limited extent, meat.

Productivity levels are low; yields per animal slaughtered or milked are estimated to be 110 kg of beef, 10 kg of mutton and 213 kg of cows' milk. Egg production from indigenous poultry is between 55 to 80, with an average egg weight of 45 g. Livestock growth rates are very slow and lag behind population growth; there has therefore been a net decline in per caput consumption of livestock products. At present, annual per caput consumptions of milk and meat are estimated to be 16 kg and 10 kg respectively. This classes Ethiopia as having the lowest consumption of meat and milk, even among neighbouring countries, although it has Africa's largest national herd.

Numerous constraints face the development of the subsector, including inadequate animal nutrition, high prevalence of diseases, low genetic potential, poor management of stock, inadequate livestock services and infrastructure (such as marketing and credit facilities), uncoordinated development programmes and absence of appropriate policies. Lack of knowledge about forage conservation and improvement of low quality feed is a major area of concern. In the highlands, cereal straw and natural hay are the most important roughages. In the mixed farming (crop-livestock) system, haymaking is traditional. In most parts of the highlands of Ethiopia, forage is usually in good supply during the rainy season, but there is an extreme shortage in the dry season. Off-season requirements can be met by preserving wet-season herbage and residues of crops. Inadequate nutrition is compounded by lack of proper technology for haymaking and storing residues.

Hay making - natural pasture

Most hay is produced from natural pasture and crop residues. Sometimes it is made from sown forage like oats and vetch. In the highlands there is bottom-land, vertisols unsuited to cropping, and up-hill land - natural pasture that could be used for hay. In the traditional management system, animals are not allowed to graze the bottom-land, which is reserved for haymaking. Bottom-land management is commonest in the northern part of the country. On the up-hill land, the animals are grazed for a short period and the area then closed and mown for hay. Hay from both sources is used during the dry period. Most of the hay in the country is from mature native grass from natural pasture, and its quality is very low (see Table 15).

The most important grasses used for hay making are *Andropogon* spp., *Festuca* spp., *Eragrostis* spp., *Hyparrhenia* spp., *Themeda* spp., *Setaria* spp., *Brachiaria* spp., *Pennisetum* spp., *Cynodon* spp., *Sporobolus* spp. and *Phalaris arundinacea*. The commonest perennial legumes in mixture with native pasture and used for haymaking are *Trifolium semipilosum* and *Trifolium burchellianum*. Farmers harvest late (November to December) once the weather is clear and dry. In pastoral areas, where livestock herding is the dominant activity, animal feeding is based on free range. Hay and the use of crop residues are not common.

Table 15. Quality of hay harvested at different times in Debre Libanos, Central Highlands, Ethiopia

Properties of natural pasture hay	**Harvest time**	
	October	**December**
Average DM yield (t/ha)	5.1	5.1
CP content (%)	9.6	5.8
CP yield (kg)	600	350
Proportion of legumes (%)	11	5.8
Natural detergent fibre (%)	61.8	66
Rumen degradable CP (RPD/MJME)(1)	7.5	3.6

Notes: (1) RDP/MJME = Rumen Degradable Protein per Megajoule Metabolizable Energy **Source:** Unpublished feed resource report, 1990. ILCA, Addis Ababa, Ethiopia.

Hay crops are mown by sickle or scythe (locally called *falch*). Almost all farmers have sickles. Farmers squat while using the sickle, which is cheap but time consuming and laborious, causing back pain. The scythe is used by a few highland farmers. Farmers wield the scythe using both hands in a standing position. It mows quickly and safely, but costs much more than a sickle. The mown hay, whether by sickle or scythe, is spread or left on the ground for 2-3 days to sun dry, a cheap and efficient method.

Once dried, the hay is collected and stacked in loose piles raised off the ground on a platform of wood or stone to avoid soil contact and spoilage. In a few areas, hay is stored in the shade. Peri-urban small-scale dairy holders store hay and straw in bales. The average weight of a bale from natural pasture or crop residues is 15-20 and 8-15 kg, respectively. The price of a bale varies depending on the season and the distance between the production area and the major livestock areas. Thus, in peri-urban areas, a bale of hay from natural pasture costs 5-6 birr during harvest time, and rises to 10-15 birr during the dry season. The price of a bale of straw is lower by half compared to that of a bale of hay.

Hay yield from natural pasture varies from place to place. Bottom-land yield is 4-5 t/ha of dry matter, while the up-hill-land pasture yield is 2-2.5 t/ha. The quality of hay from these pastures is very low, mainly due to late harvesting. A study carried out by the International Livestock Centre for Africa (ILCA) indicates that early harvesting improves the crude protein content (Table 16). Hay is fed mainly to milking animals, calves, and oxen, and to some extent to small ruminants.

Crop residues

Crop residues, especially cereal straws and maize or sorghum stover are the major feed source for prolonged dry-period feeding in Ethiopia. According to the 1995 agricultural crop yield survey, a total of 4.5 million tonnes of dry matter of crop residue are produced. Crop residues are available from cereals such as teff, wheat, barley, maize and sorghum, as well as pulses like peas, beans and chick-pea. Crop residues are collected and stacked in field in the same way as hay from the natural pasture.

Figure 48. Sorghum stover protected by thoms (near Jijiga, Ethiopia)

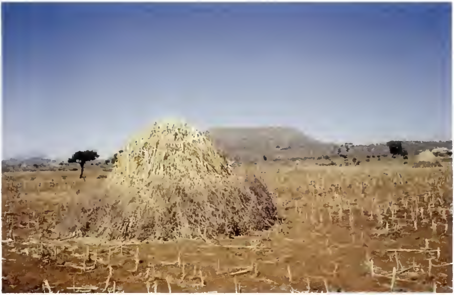

Table 16. Analyses of some Ethiopian crop residues

Type	DM	EE	Ash	CP	NDF
Barley straw	92.6	2.3	8.4	4.7	71.5
Teff straw	92.6	1.9	8.4	5.2	72.6
Wheat straw	93.1	1.2	9.0	3.9	79.8
Fava bean residue	91.7	0.8	10.4	7.2	74.3
Field peas residue	91.9	1.2	6.1	6.7	73.6
Natural pasture hay	92.2	1.5	9.5	6.6	73.8

Key to columns: DM = dry matter; EE = ether extract; CP = crude protein; NDF = neutral detergent fibre

The feeding of crop residue to livestock is highly regarded in the highland mixed farming system. Farmers give most of the straw to oxen and milking cows; any surplus will be given to sheep. Goats are not usually given crop residues. Residues are fed without treatment. In addition to being fodder, residues are used for house construction and fuel.

Sown forage

This is a new concept for Ethiopia. Attention to forage development increased after the Fourth Livestock Development Project of the Ministry of Agriculture. Forage is used by dairy development and fattening programmes. Most is used for cut-and-carry feed or haymaking. The common forage crops in Ethiopia are oats/vetch, and Rhodes grass. Tree legumes like *Sesbania,* tree-lucerne (*Chamaecytisus* (syn. *Cytisus*) *palmensis*), and *Leucaena* are grown and used for cut-and-carry. The DM yield ranges between 5-10 t/ha, with CP about 15-30%. Seeds of forages are produced under contract by farmers, and also on government ranches and nurseries. Forages for cut-and-carry feeding and haymaking are produced in backyards, undersown on cereal crop land, from soil and water conservation structure areas, livestock exclusion areas and established pasture areas (i.e., small-scale dairy farmer areas). Forage from improved lands is used for feeding about half the cross-bred milking cows, calves and young bulls in fattening programmes.

Suggestions for interventions

To improve the quantity and quality of hay from different feed resources, the following should be considered for future intervention programmes:

- Encouraging farmers to harvest hay early, i.e., before the plant matures.

- Proper drying and storage of hay (i.e., stacking and storing) off the ground on a platform made of wood or stone to avoid spoilage. Preparing shade for protection of the hay from heavy sunlight is also very useful.
- Improving utilization of crop residues and poor quality natural pasture hay. This can be done by adding or mixing the feed with herbaceous and tree legumes to improve the quality.
- Establishing improved herbaceous forage tree legumes, so that leaves and branches can be used as a protein source in small-scale dairy farm development.

CASE STUDY 2. LA PRODUCTION DE FOIN AU SAHEL ET EN SAVANE EN AFRIQUE DE L'OUEST[1] [HAY IN THE SAHEL AND SAVANNAH ZONES OF WEST AFRICA]

ENGLISH SUMMARY

Stock-rearing in the Sahel is dominated by cattle, sheep and goats. In sedentary production systems, herds of two to sixty head are kept on the village lands throughout the year. Transhumant herders move to grazing and water, and also to markets: their herds are always over sixty head. Management is similar for both systems. During the rains, stock are taken to pasture at night and return for milking at 8 or 9 a.m., then return to graze until nightfall. The herders rest after evening milking, and set out again late at night.

By harvest time the grass is mature and lignified, and the grazing is no better than straw. The remaining water points are surrounded by fields and conflicts can occur. Once the crops are harvested, stock graze the fields. In recent years, however, farmers increasingly harvest and store their crop residues, for their own use or for sale. Haymaking technology is now being introduced, with a considerable extension thrust.

In the Sahel, the rains fall between June and October. From November the standing grass is dead and very poor feed. Despite great seasonal feed scarcity, hay was not made in the Sahel, except in very small quantities to feed the family horse, usually from *Alysicarpus glumaceus* and *Rottboellia exaltata*; only enough was made for the horse's needs. Early attempts to introduce haymaking by expatriate technicians failed, but the severe droughts of 1973 and 1984 made traditionalists more receptive to new ideas on fodder conservation.

For haymaking to be accepted and to increase, a suitable institutional framework was needed. In the Sahel, this involved: (i) organizing haymakers into groups to increase solidarity and gather together interested stock-owners; this was done though *L'Association pour la Promotion de l'Elevage au Sahel et en*

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[1] Based on material provided by Boubacar Ly.

Savane (APESS) that, since 1988, has spread to fifteen Sahelian states. (ii) Training through group sessions. (iii) Information from APESS through its journal *Jawdi Men*. (iv) Visits between stock-owners. (v) APESS meetings.

Haymaking sites should be chosen with at least part of the area on low-lying land that collects runoff. This assures production from the higher areas if rainfall is excessive and from the bottom-land when the rains are normal or low. Further advantages are the floristic diversity over the range of conditions, and spread of the haymaking work in time: the herbage on higher, well drained land is ready for haymaking early, whereas the bottom-land matures later. Hay land is prepared by: marking the boundaries; clearing the land of stones, stumps, bushes (although large and useful trees are left in place); fencing with thorn branches; using it for night-penning of livestock to raise fertility before the rains; then broadcasting seed of local herbage at the onset of the rains.

Wild plants thought good for hay by the population include: *Alysicarpus ovalifolius, A. glumaceus, Andropogon gayanus, Brachiaria ramosa, Cenchrus biflorus, Dactyloctenium aegypticum, Echinochloa stagnina, Ipomoea vagrans, Panicum laetum, Pennisetum americanum, P. pedicellatum, Rottboellia exaltata* and *Zornia glochidiata*. Sown fodders recommended by APESS include siratro (*Macroptilium atropurpureum*) and *Andropogon gayanus*.

Metal-framed scythes are recommended for mowing; turning and collection is by rake; and transport by ox cart. Mowing starts early, when the dew is still on the herbage, and stops before noon. By four in the afternoon the first hay will be dry enough to be put in store - uncompacted. The standard APESS hay barn is 4 m wide, 1.7 m high at the walls, and 3.5 m at the centre; the usual length is 8 m. The pillars may be in wood or brick; the roof and walls are covered in matting. Haymaking begins in mid-August and continues to mid-October. Yields depend on the vegetation and the strength and skill of the mower; measurements by APESS indicate a mean daily production of 150 - 200 kg per person, so enough to supplement the feed of one cow throughout the dry season needs four workdays.

Common crop residues include millet straw and the haulms of cowpea and groundnut. Millet is often cut green for fodder, before the grain is ripe, if grain harvest is unlikely due to either inadequate rain or the onset of stock grazing the fields. Residues are stored in trees and on and around houses. Some residues are sold; fodder markets are usual alongside cattle markets; green feed, bush hay and crop residues are all sold; green fodder is the most highly prized.

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L'ÉLEVAGE AU SAHEL

L'élevage dans les pays du Sahel de l'Afrique de l'Ouest est dominé par les bovins, les ovins et les caprins. Traditionnellement on élève également des chevaux, des ânes, des poulets et des pintades. Grâce aux techniques de l'Occident, l'élevage semi-industriel des porcs, des volailles, ainsi que des lapins, a fait son apparition. Nous parlerons ici de l'élevage des espèces suivantes: les bovins, les équidés, les ovins et les caprins. Il y a deux sortes d'éleveurs: ceux qui pratiquent la transhumance qui est un déplacement saisonnier pour résoudre trois problèmes à la fois: nourrir les animaux par la recherche de pâturages, les abreuver sur des sites qui ne nécessitent pas l'exhaure toujours très contraignante, et la possibilité de vendre du lait et des animaux affaiblis, au niveau de marchés importants. Les transhumants ont toujours des troupeaux d'au moins 60 unités. Les éleveurs sédentaires possèdent des troupeaux de l'ordre de 2 à 60 têtes et les gardent dans l'espace villageois toute l'année.

La conduite journalière des animaux, par les transhumants comme par les sédentaires, se déroule comme suit: en saison des pluies, les animaux vont sur les pâturages la nuit et reviennent le matin entre 8 et 9 heures, puis ils sont traits. Ils repartent vers les pâturages pour revenir à la tombée de la nuit. Après la traite du soir, le berger mange et se repose un peu puis, tard dans la nuit, il repart avec les animaux. L'eau pour s'abreuver ne pose pas de problèmes car il y a des petites mares partout et il y a aussi des affleurements de terres salées qui couvrent les besoins des animaux en sels minéraux. Les maladies principals sont provoquées par les tiques, les protozoaires et les parasites internes. La saison des pluies est la période des saillies avec les naissances en mai. Au moment des récoltes des champs de mil (octobre et novembre), le pâturage est déjà appauvri car presque toutes les graminées sont devenues paille ou ont atteint un trop grand degré de lignification. Les points d'eau conservant encore un peu d'eau sont presque partout entourés de champs et, en voulant y accéder, les animaux font des dégâts sur les champs et beaucoup de conflits naissent de cette situation. Certains conflits sont aussi dus à la négligence scandaleuse des bergers qui laissent les animaux dévaster en une nuit toute ta récolte d'une année de travail. Après les récoltes, les animaux peuvent accéder aux résidus de celles-ci dans les champs. Depuis quelques temps maintenant, les agriculteurs ramassent et stockent ces résidus pour les donner à leurs animaux en saison sèche ou pour les vendre.

En saison froide, la pénurie alimentaire s'installe. Les herbes sont presque toutes devenues sèches et les arbres ont perdu leurs feuilles. La vie des éleveurs et celle des animaux est vraiment pénible. Les hommes comme les animaux attrappent des refroidissements se prolongeant par des bronchites et des pneumonies aux conséquences parfois fatales.

En saison sèche (mars à mai), la faim, la soif, les maladies et l'inconfort s'abattent sur les animaux et sur les humains. Les animaux maigrissent et deviennent stériles. A cette période, certains sont tellement amaigris que leurs muscles ne leur permettent plus de se relever une fois qu'ils sont couchés. Les éleveurs sont obligés de se mettre à plusieurs pour aider ces animaux à se dresser.

Lorsque la saison des pluies est tardive, les naissances interviennent en avril et mai, c'est-à-dire aux pires moments pour les mères et les petits. Malgré cette situation vécue au Sahel depuis toujours, les éleveurs n'ont pas pensé à introduire la pratique du foin et les outils correspondants pour un grand nombre d'animaux. Pour les chevaux, dont les familles possèdent en moyenne une unité, une sorte de foin, l'*Alysicarpus glumaceus* et la *Rottboellia exaltata,* existe traditionnellement. Mais cela s'arrêtait seulement aux besoins des chevaux et pour une couverture de deux ou trois mois.

Le foin - Généralités

Le Sahel et la savane en Afrique de l'Ouest connaissent une saison de pluies qui dure de juin à octobre. Durant ces cinq mois, l'herbe verte est disponible et les animaux qui la consomment sont très productifs génétiquement Mais, dès novembre, l'herbe devient de la paille (sans vie) et les animaux n'ont que cette paille pour s'alimenter jusqu'en juin. Cette période morte est celle qui pénalise la production des animaux et même leur survie. Cela a toujours existé et l'idée de récolter l'herbe verte nutritive, de l'apprêter pour la conserver tout en lui préservant ses vertus nutritives, n'a pas été considérée au Sahel et dans la Savane. Quelques techniciens européens ont bien tenté d'implanter cette idée avant l'indépendance des pays mais leurs tentatives sont restées confinées dans les stations de recherche et les fermes pilotes. Ils n'avaient pas trouvé la manière de transmettre ce message pour qu'il soit bien reçu et mis en pratique. Mais les sécheresses de 1973 et de 1984 ont modifié l'élevage et les mentalités des éleveurs traditionnels. Quelques-uns se sont ouverts aux nouvelles idées, sont devenus plus réceptifs, plus désireux d'enrichir leur pratique de l'élevage. C'est en raison des effets cumulés des sécheresses de 1973 et de 1984 que l'idée de faire du foin est remontée dans les esprits et a été tentée à une grande échelle et directement avec des éleveurs pratiquants. L'idée s'est depuis imposée comme une évidence et une nécessité. Il est devenu évident qu'au moment où l'herbe est la plus nutritive et la plus abondante, il faut en récolter la plus grande quantité possible, la traiter par le séchage direct par le soleil et la stocker là où elle conserve l'essentiel de ses qualités nutritives.

Proposition et utilisation du foin chez les éleveurs

La proposition de produire du foin a été faite aux éleveurs en rapport direct avec l'objectif constant de tout éleveur: avoir du lait tous les jours et un troupeau qui se multiplie bien et qui grandit. Le lait nourrit, soigne, apaise, solidarise, apporte de l'énergie, enrichit et honore. Les naissances sont toujours des moments de joie, d'émerveillement, d'espérance. Le lait comme base et des naissances régulières constituent deux facteurs certains de vie heureuse et d'évolution réussie. Les éleveurs connaissent bien tout cela et lorsqu'on leur a expliqué que le foin engendrait du lait tous les jours toute l'année et des naissances régulières, ils ont accepté de tenter cette opération sans se dérober. Le suivi qui a été mis en place pour les soutenir a permis d'obtenir en deux ans des résultats très convaincants. Bien qu'ayant vite compris l'idée, les éleveurs se sont posé au moins quatre grandes questions:

1. Si tout le monde se met à faucher l'herbe pour en faire du foin, est-ce qu'il restera au bout de quelques années assez de semences pour faire pousser l'herbe?
2. Est-ce que l'on peut faucher pour nourrir cent animaux?
3. Comment faire pour protéger l'herbe des animaux qui broutent et qui piétinent pour pouvoir la faucher avec de bons rendements?
4. Est-ce que l'on pourra vendre du lait si tout le monde en produit toute l'année?

A ces questions, les réponses ci-après ont été données:

Concernant la question 1. Il y a des gisements inépuisables de semences d'herbes dans la terre et des fauches répétées en un lieu n'empêchent pas le même sol de se recouvrir d'abondantes herbes les années suivantes. Le vent d'une part, et le ruissellement des eaux d'autre part, sont des pourvoyeurs réguliers de semences d'herbes. Les animaux, par leurs déjections, approvisionnent les sols en semences d'herbes. Il y a aussi la possibilité de laisser des bandes d'herbes non fauchées pour qu'elles fructifient et déposent leurs fruits. Enfin, si tout cela ne suffit pas, on peut récolter des semences fourragères et les ensemencer à la volée, en poquets ou en raies sur le terrain choisi, immédiatement après la première bonne pluie d'hivernage.

Concernant la question 2. Nourrir cent animaux avec le foin est possible. Il y a quatre facteurs à posséder et cinq à maîtriser: un espace riche et étendu permettant de produire des herbes qui donneraient un bon rendement en foin; un instrument de fauche rapide et performant (pour une centaine d'animaux, dix faucheurs avec leurs faux ou une motofaucheuse peuvent récolter de quoi suffire à leur alimentation en saison sèche); un instrument de transport rapide et pouvant porter de grands volumes (la charrette hippomobile à quatre roues est tout à fait appropriée). Mais en attendant l'acquisition d'une telle charrette, des enfants en grand nombre et rendus joyeux par des cadeaux (bonbons) peuvent être très efficaces. Une infrastructure de stockage qui met ce foin à l'abri des intempéries (soleil, vents, poussières, pluies) et des prédateurs (animaux, insectes etc.) constitue le dernier facteur .

Concernant la question 3. Pour que l'herbe ne soit pas endommagée et gênée dans sa croissance par les animaux qui broutent et piétinent, il faut la protéger. Cela est possible avec du grillage, mais celui-ci est trop cher, du bois mort, mais cela dégrade la végétation, le plus avantageux est une haie vive. L'arbuste *Ziziphus spina-christi* est le plus indiqué. Ses fruits sont délicieux pour les humains et les petits ruminants, ses feuilles sont très recherchées par ces derniers. Ses branches flexibles et épineuses s'entrelacent bien pour constituer une sorte de maille qui arrête les animaux. Sa germination est très facile et sa croissance très rapide, en deux à trois ans, il est déjà assez grand pour constituer une barrière. C'est en plus un arbuste reconnu par le christianisme, l'islam et certaines pratiques culturelles en Afrique comme symbolisant la limite, la barrière.

Concernant la question 4. Si les éleveurs produisent tous du lait et toute l'année, l'écoulement de ce lait se fera par sa transformation dans des laiteries et fromageries régionales. Des consommateurs insatiables de lait et de produits laitiers existent partout dans le monde. Un pays comme le Nigeria peut consommer à lui seul toutes les productions des pays du Sahel, du Sénégal au Tchad. Avec une production régulière et importante de lait, les éleveurs sont dans la meilleure position pour être ni affamés, ni pauvres, ni malades, ni déméritants, et être indépendants.

Propagation de l'idée et de la pratique du foin

Pour que l'idée et la pratique du foin se maintiennent et s'étendent, il faut mettre en place des dispositifs de réalisation, de propagation, de protection et de perfectionnement. Ce sont: 1. l'organisation des pratiquants: ceux-ci s'organisent avec la conscience de se perfectionner et d'augmenter le nombre de pratiquants qui tous renforceront le groupe. L'Association pour la Promotion de l'Elevage au

Sahel et en Savane (APESS) en est une illustration. Créée en mai 1989, elle a réussi par son organisation à être présente dans une quinzaine de pays du Sahel et de la Savane en Afrique de l'Ouest en moins de sept ans. Son fondement est justement la production fourragère (foins et cultures fourragères vivaces); 2. les formations: les éleveurs comprennent mieux, s'enrichissent et s'enthousiasment mutuellement lorsqu'ils se retrouvent dans des sessions de formation; 3. l'intérêt des formations est de reconstituer dans l'esprit des éleveurs les pièces qui composent l'élevage, leur ordre logique de viabilité, leurs proportions, la qualité nécessaire pour chaque pièce, les critères de reconnaissance dans la nature de chaque pièce dans sa qualité optimale, et les conditions de son obtention au meilleur compte. Ainsi les éleveurs découvrent les tenants et les aboutissants de l'élevage, qui laisse apparaître la fondamentalité de l'éleveur: sa prédisposition à l'élevage qui s'exprime par son rêve, la qualification qui lui est nécessaire et que lui procure la formation, et les courants porteurs de la concrétisation de son rêve que sont les valeurs culturelles universelles, celles qui l'amènent inéluctablement à se dépasser, donc à progresser.

L'information à la portée des éleveurs

Tout éleveur sahélien est culturellement sensible à la connaissance et à la beauté. En conséquence, si l'information enrobe la connaissance dans la beauté et se présente aux éleveurs à leur porte, ils seront touchés et finiront par réagir. C'est cela que l'APESS a essayé d'atteindre avec sa revue *Jawdi Men* qui paraît depuis 1993. Les visites entre éleveurs: il y a dans chaque société des personnes (famille) qui reçoivent beaucoup de visiteurs et toute l'année. Elles sont très importantes pour la diffusion. Lorsqu'elles pratiquent une innovation, beaucoup de personnes y prennent part et tentent d'imiter, de reproduire. Ce sont des personnes précieuses pour l'introduction et la propagation des innovations. L'événement est aussi un facteur indispensable à l'imprégnation d'une idée et à sa propagation. Il libère et dilate les émotions des gens qui ainsi deviennent très réceptifs pour absorber et assimiler les messages de l'idée. Par exemple l'APESS a créé son assemblée générale sous la forme culturelle d'un événement. Grâce â cette assemblée générale, l'APESS et son fondement, le hangar rempli de foin, ont franchi toutes les frontières des pays et de cultures. L'événement, surtout répété régulièrement, marque les gens de façon indélébile.

La pratique du foin: l'acteur, l'éleveur, l'agriculteur

Celui qui produit du foin est une personne qui a de la perspective, qui anticipe, qui a le sens de la continuité et de la régularité, de la constance. Avec ces qualités, une personne peut facilement se développer et développer d'autres personnes. La pratique du foin est un révélateur du caractère des individus et de leur potentiel plus ou moins fort à se développer. Pour être un bon travailleur, il faut connaître pour pouvoir agir, savoir observer pour connaître mieux et d'avantage, être travailleur pour concrétiser, être calme pour supprimer toute agressivité, être rigoureux, persévérant pour tout surmonter, être appliqué, soigné, fin pour tout qualifier, aimer son travail dans ses différents embranchements pour tout imprégner de bienveillance, s'y plaire et s'y maintenir. C'est à l'occasion des formations que l'éleveur prend conscience et connaissance de cela. Ces formations sont donc nécessaires pour toute entreprise que l'on veut installer ou faire progresser.

Le terrain à foin

Le terrain pour produire du foin doit être choisi avec beaucoup de soin pour amortir et reculer tous les débordements et toutes les pénuries agroclimatiques. Le terrain doit partir au moins du centre d'un bas-fonds de ruissellement des eaux et s'étendre perpendiculairement à ce bas-fonds jusqu'aux parties hautes. Ceci a l'avantage de garantir toujours une production sur les parties hautes quand il pleut trop, sur les bas-fonds lorsque les pluies sont insuffisantes et irrégulières. Le deuxième avantage est que les herbes sont diversifiées, celles qui poussent dans les bas-fonds sont différentes de celles qui poussent en hauteur. L'étagement du terrain du bas-fonds vers la crête permet donc d'avoir différentes espèces fourragères. Le troisième avantage est que ces différentes variétés d'herbes sont bonnes à faucher à des périodes différentes, ce qui allonge le temps de fauche en le répartissant sur 30 à 60 jours selon les terrains et les variétés d'herbes qui y poussent.

Le terrain doit être préparé pour donner aux herbes les meilleures conditions pour se développer et aussi pour faciliter et bien rentabiliser la fauche. Il faut donc délimiter et piqueter la parcelle, défricher et dessoucher en ne conservant que les grands arbres (fruitiers ou qui ont une autre utilité) s'ils existent, enlever tous les cailloux, les souches et les troncs d'arbres, clôturer avec les branchages enlevés, en faire un lieu de séjour nocturne des animaux afin qu'ils y déposent leurs déjections qui sont une très bonne fumure; dès la première bonne pluie, épandre à la volée les semences d'herbes qu'on aimerait faucher. Il faut auparavant les avoir ramassées dès la fin de leur fructification.

Les herbes à faucher

Les déclarations des éleveurs, les analyses bromatologiques et les effets des foins sur les animaux qui les ont consommés s'accordent sur les herbes ci-après comme les meilleures:

Table 17. Plantes préférées pour le foin au Sahel [Preferred hay plants in the Sahel]

Noms scientifiques	en fulfulde	Noms scientifiques	en fulfulde
Panicum laetum	pagguri	*Dactyloctenium aegyptium*	burgel
Brachiaria ramosa	pagguri	*Andropogon gayanus*	dayye
Pennisetum pedicellatum	bogodolo	*Alysicarpus ovalifolius* ou *A. glumaceus*	
Cenchrus biflorus	kebbe	*Zornia glochidiata*	dengeree
Rottboellia exaltata	nielo	*Pennisetum typhoides*	gawri
Ipomoea vagrans	layndi	*Echinochloa stagnina*	burgu

Il y a des herbes qui sont vivaces et qui se prêtent aux cultures fourragères. Les plus réussies dans la pratique généralisée des cultures fourragères par les membres de l'APESS sont le siratro *(Macroptilium atropurpureum*) et l'*Andropogon gayanus.*

Les outils de la fauche et du foin

Le fait que la main d'œuvre est peu coûteuse (lorsqu'elle existe) invite à utiliser la faux pour la récolte de l'herbe pour les foins. En multipliant les faucheurs, on peut obtenir de très grandes quantités de foin si l'espace fauché est vaste, bien préparé et bien fourni en herbes. Pour rassembler le foin, le râteau est indiqué et pour le charger sur la charrette, la fourche convient tout à fait. Pour le transport du foin des lieux de ramassage aux lieux de stockage, une charrette volumineuse et stable tirée par un cheval est le meilleur instrument. A défaut de cela, le recours à des enfants encouragés par de petits cadeaux peut apporter une solution à la fois économique et éducative. L'aspect fondamental à exiger pour les outils est que ceux-ci obligent à travailler debout et en extension maximale. Pour de grandes entreprises agricoles, la motofaucheuse peut remplacer les faux.

Les infrastructures de stockage du foin

Plusieurs variétés d'infrastructures sont possibles. L'APESS recommande le hangar étanche double pente ayant 8 m de long, 4 m de large, 3,5 m de hauteur centrale et 1,7 m de hauteur latérale. Les piliers peuvent être en bois ou en briques de terre. Les côtés peuvent être garnis de *seccos* (nattes) de paille ou de murs en briques de terre. La toiture est recouverte de *seccos* et de chaumes qui assurent son étanchéité. L'infrastructure doit dans tous les cas se prêter à l'intérieur à des mouvements amples pour ne pas limiter le potentiel de travail de l'éleveur.

Périodes de la fauche

Dans la journée, il faudrait commencer très tôt quand la rosée tient et alourdit un peu les herbes. On fauche jusqu'à 11 heures ou midi puis on arrête la fauche et, vers 14 h, on retourne les herbes fauchées de sorte qu'elles soient asséchées de tous les côtés. Vers 16 h, on commence à ramasser les premières herbes fauchées pour les rentrer en grange (hangar APESS). Il ne faut pas les attacher en bottes, car elles pourraient être envahies par les moisissures. Dans l'année, la fauche commence après la période des pluies fines et répétées plusieurs fois par jour. Au Sahel, cette période se situe autour du 15 août en année normale de saison de pluies. Pour ceux qui savent les lire, les étoiles aussi indiquent bien nettement la période convenable. Avec le mûrissement étagé des herbes, la fauche peut se poursuivre jusqu'au 15 octobre soit près de soixante jours après son démarrage.

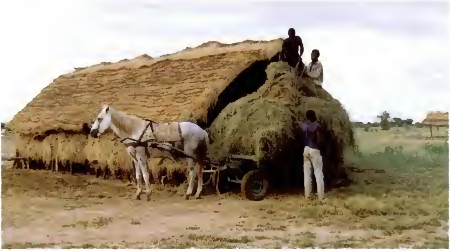
Pratique de la fauche

Il faut disposer d'une faux, d'une pierre à affûter et d'un récipient contenant de l'eau pour tremper la pierre à affûter. On fixe bien la lame de la faux en vérifiant si l'angle de coupe est optimal. On affûte alors la faux. Avant de faucher, il faut vérifier qu'il n'y ait ni cailloux, ni bois, ni souches d'arbres sur le parcours à faucher. On fauche par un mouvement de rotation du tronc dont le rayon reste constant entre le moment où la lame touche les herbes et celui où le mouvement s'arrête. On prend de petites épaisseurs d'herbes et on avance pas à pas jusqu'à la fin de la parcelle. Cette méthode permet de faucher des bandes régulières et l'herbe peut être ramassée facilement en suivant les bandes plus tard avec la charrette. Lorsqu'on est fatigué, ou lorsque la lame ne coupe plus très bien, il faut s'arrêter et affûter celle-ci.

Rendements

Les rendements dépendent de la nature des herbes (certaines sont moins hautes et moins denses), de la richesse du terrain qui conditionne la biomasse, de l'habileté et de la résistance du faucheur et enfin de la qualité de la faux. Avec tout cela inclus, les mesures de rendement faites donnent la valeur moyenne de 150 à 200 kg de foin par jour par faucheur. Ainsi, un faucheur peut récolter en 4 jours de quoi nourrir en complément une bonne vache pendant la saison sèche, soit de 600 à 800 kg de foin.

Figure 49. Demonstrating appropriate technology in the Sahel (Dori, Burkina Faso)



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Utilisation du foin

Le foin est destiné à nourrir les animaux en saison sèche quand l'herbe est devenue paille morte. Il est logique aussi de le donner aux animaux les plus valorisateurs de ce foin. Avec le lait, le fumier et l'énergie, l'espèce bovine est de loin la plus valorisante, suivie de près par les chevaux. Dans l'espèce bovine, les femelles en lactation sont les plus intéressantes. Elles donnent du lait, beaucoup de fumier, sauvent et font grandir leurs veaux pendant la saison sèche grâce au lait qu'elle donnent chaque jour. Les veaux encore jeunes ainsi que les animaux malades constituent la deuxième priorité d'animaux pouvant bénéficier du foin. Le foin est à servir à ces animaux le matin et le soir pour les vaches en lactation dès que leur production baisse et pour les animaux malades à l'instant même où la maladie s'est manifestée. Quant aux jeunes, ils peuvent recevoir le foin dès qu'ils sont en âge de le consommer. Le meilleur endroit pour distribuer le foin aux animaux est l'aire des champs de cultures. Les animaux y sont à l'aise (espace vaste et propre) et y déposent leurs déjections (bouses et urines) qui fertilisent les champs à peu de frais. Les quantités à servir se déterminent normalement par les animaux eux-mêmes en fonction de leurs besoins. Mais le plus souvent le foin est en quantités limitées et doit être fortement rationné. Les pratiques courantes qui ont donné de bons résultats (en lait, saillies et poids) sont de l'ordre de 3 à 4 kg de foin par jour par vache adulte. Cette quantité correspond à un complément car l'animal va au pâturage et y trouve de la paille et peut aussi parfois recevoir du tourteau ou des graines de coton.

La distribution du foin aux animaux a donné les résultats ci-après (données de l'APESS). Augmentation de la production de lait: de l'ordre de 30 à 60% par rapport à la production sans distribution de foin. Augmentation du volume du fumier qui atteint au moins 50% du volume lors de la saison de pluies. Reprise des saillies des femelles trois semaines après la distribution du foin pour au moins 80% des femelles qui ont reçu le foin. Le foin s'utilise aussi comme produit à vendre. Au Sahel, c'est même le produit végétal le plus recherché et le plus enrichissant. Il devrait être considéré comme un produit de rente par excellence. En Savane aussi, du fait de la lignification importante des herbes, le foin peut revêtir une très grande valeur. Il faudrait par conséquent développer d'importantes actions pour répandre cette pratique dans les régions soudaniennes.

Pratique du foin dans l'espace

On peut mesurer la propagation de la production de foin en Afrique de l'Ouest en se référant à l'expérience de l'APESS. Directement et indirectement, l'APESS, créée en 1989, a réussi en 1997 à faire pratiquer la production du foin dans les pays ci-après: Burkina Faso: toutes les régions du pays; Mali: le Delta (Macina) le Sdno (Bankass-Douciitza); Sénégal: Fleuve, Ferlo; Niger: Tomodi, les Dallol Dogondoutchi, Maradi; Mauritanie: Fleuve; et Cameroun: Adamaoua, le Nord. L'idée et la pratique du foin sont donc bien répandues et bien enracinées. Il reste à leur donner une plus grande ampleur et qualité au niveau des éleveurs pratiquants. C'est là un travail d'information, de formation, de suivi et d'organisation des éleveurs.

Cultures fourragères

L'intérêt des cultures fourragères est de fournir de la verdure en saison sèche. Seules sont donc intéressantes les cultures vivaces. Parmi celles-ci, deux ont donné de très bons résultats: *Macroptilium atropurpureum* ou siratro qui est une légumineuse importée d'Australie et *Andropogon gayanus* qui est une graminée locale. Tandis que, en saison sèche, le siratro réussit bien en Savane, on constate quelques difficultés au Sahel où les insectes rendent cette culture difficile. Il se peut donc qu'on ait plus de chance au nord avec *Alysicarpus ovalifolius* car, en terrain sableux (dunes), ces plantes donnent d'excellents résultats. Pour le siratro, il faut choisir un terrain humide, de préférence dunaire, et en savane dans des bas-fonds où l'eau ne stagne pas; il faut défricher, dessoucher le terrain, semer en début de saison des pluies, de préférence après un labour du terrain, sarcler dès que d'autres herbes s'installent ou quand le sol se durcit, clôturer avec du grillage (trop cher) ou du bois mort pour protéger le siratro et la haie vive à mettre en place. La meilleure plante pour installer une clôture sous forme de haie vive est le *Ziziphus spina-christi.* Il faut procéder ainsi: récolter les graines mûres dégagées de leur pulpe, les casser pour extraire les vraies graines, en début de saison des pluies, dès la première grande pluie, les semer tout au long du périmètre de la parcelle fourragère, semer après avoir trempé les graines 24 heures dans l'eau, mettre 5 à 10 graines par poquet, entre les poquets; une distance de 50 cm est conseillée; il est avantageux de mettre du fumier au pied des pousses pour accélérer leur croissance en saison des pluies, ainsi elles développeront un réseau important de racines, leur permettant de franchir la sécheresse de saison sèche.

Lorsque les plantes de siratro ont atteint une certaine taille de développement et que les premières feuilles commencent à apparaître, il faut récolter le fourrage en coupant toutes les branches de la plante. Il faut couper à trois doigts de hauteur (environ 3 cm). Il est important de couper toutes les tiges et surtout de le faire avant que la plante ne vieillisse. La plante repousse bien lorsqu'elle a toujours la vigueur de la croissance. A un âge plus avancé, elle est en phase de décroissance et sa force de rejet est bien diminuée. Après la récolte et selon le degré d'humidité de l'air ambiant, il faut la laisser se faner pendant un à deux jours, parfois trois. Puis il faut enrouler les tiges coupées en bottes et les stocker dans le hangar étanche (voir paragraphe concernant le foin). Les repousses de siratro atteignent leur taille adulte quatre à six semaines après une coupe. Cela dépend de la richesse et du degré d'humidité du terrain et aussi de la qualité des travaux faits pour les plantes. Lorsque la parcelle est bien clôturée, on peut faire de quatre à cinq récoltes en saison sèche si le terrain et les travaux exécutés sont bons. Si on arrose en supplément, les plantes repoussent bien mieux encore. Le siratro se donne en sec lorsqu'il est produit en saison de pluies et en vert lorsqu'il est récolté en saison sèche. Il faut donner ce fourrage à volonté aux animaux car ils peuvent rarement dépasser les 2 à 3 kilos. Lorsque le fourrage est vert, l'état de l'animal et ses productions se modifient favorablement en une semaine. Le siratro cultivé sur un bon terrain et ayant bénéficié de travaux soignés peut subsister de trois à cinq ans avant de renouveler le semis. Dans l'année, pour les différentes fauches, il peut donner un rendement de l'ordre de 2 à 10 tonnes de foin.

Pour l'*Andropogon gayanus,* il faut: choisir un terrain sur lequel il existe déjà ou sur lequel on sait qu'il se développe; il faut défricher, dessoucher le terrain, semer par dispersion massive de graines (des épillets) ou par repiquage des éclats de souche, sarcler si possible en enlevant d'autres herbes pouvant être gênantes, installer une clôture étanche et permanente, arroser s'il y en a la possibilité, récolter avant que les tiges ne se lignifient, laisser se faner un à deux jours avant de mettre à l'abri dans le hangar, en saison sèche, on peut récolter les repousses vertes et les donner aux meilleures laitières.

La pratique des cultures fourragères est très difficile et son extension très faible en milieu éleveur sahélien. Le manque d'habitude de cultiver et surtout de constance au travail en saison sèche ne permet pas un grand développement des cultures fourragères en milieu éleveur. Les services techniques de l'agriculture et de l'élevage font quelques essais de cultures fourragères mais surtout avec les plantes annuelles. La plus répandue est la dolique *(Lablab purpureus).* Les éleveurs sont pour l'instant très prudents à les adopter.

Les résidus de récolte

Ce sont surtout les fanes de haricot, d'arachide et les tiges de mil plus ou moins parvenues à maturité. Une pratique au Sahel consiste à récolter le mil en vert et sur le point de fructifier comme fourrage, car on sait que, en cas de faible pluviométrie, l'entrée des animaux dans les champs ne leur permettrait pas de fructifier jusqu'au bout. La qualité de ces résidus est très variable selon le stade de développement végétatif auquel on les a récoltés. Le plus souvent, ils sont transportés par des charrettes à âne jusqu'à leur lieu de stockage. Les résidus de récolte sont stockés sur les arbres et sur les toits de maisons en terrasse. Une bonne partie est endommagée par les rayons solaires. Les résidus de récolte sont vendus par certains, utilisés pour leurs animaux par d'autres. Les laitières et les animaux à l'engraissement en sont les principaux bénéficiaires.

Vente des fourrages et résidus de récolte

En réalité, le foin, les fancs de haricot et d'arachide, les tiges de mil et la simple paille jaune de brousse sont un important flux commercial entre campagnes et villes entre agriculteurs et éleveurs. Le marché du bétail est toujours flanqué de son marché de fourrage de toutes sortes de qualités. Les prix sont très variables, liés d'abord à la rareté des fourrages d'une année sur l'autre, d'une saison à l'autre, d'une région à l'autre, et à la qualité du fourrage. Les fourrages encore verts sont les plus demandés et les mieux achetés. Malgré cela, le réflexe d'en produire beaucoup ne s'est pas encore installé dans les esprits. Normalement le fourrage devrait être la première culture de rente interne au Sahel. Mais les éleveurs n'ont pas eu ce réflexe économique et les techniciens ne les ont pas exhortés dans ce sens. Avec la naissance de laiteries dans certaines régions, il est sûr que finalement des personnes avisées vont se consacrer à la production de fourrages en grandes quantités. L'installation d'usines de lait exigeant que celui-ci provienne d'élevages laitiers dont les animaux sont principalement nourris de fourrage amorcera au Sahel une heureuse adaptation de l'élevage.

L'IMPORTANCE DE LA VULGARISATION DU FOIN POUR LE DÉVELOPPEMENT SOCIO-ÉCONOMIQUE DU SAHEL

Le succès et les expériences de l'APESS dans la vulgarisation de la production fourragère ouvrent de nouvelles perspectives et un nouvel espoir pour la région du Sahel. Le Sahel n'est pas une région pauvre, mais une région de potentiel économique en sourdine. Si les habitants du Sahel attendent aujourd'hui la pitié des projets, c'est parce que la politique ainsi que l'administration ont attendu jusqu'ici que ces projets de développement combattent les pénuries et la peur de catastrophes comme par exemple les grandes sécheresses. Ainsi s'est cultivée au niveau de la population rurale une attitude fataliste d'attente et de passivité peureuse. C'est là le vrai handicap du développement socio-économique du Sahel. Les difficultés écologiques, climatiques et démographiques qui constituent les problèmes actuels sont, selon quelques experts, les facteurs principaux du blocage du développement seulement au second plan. C'est-à-dire qu'elles sont surmontables si les producteurs et productrices ruraux ont l'audace, la volonté ferme, les connaissances utiles et l'encouragement de la part de la politique et de l'administration pour travailler et faire valoir le potentiel de cette région. Les expériences de l'APESS montrent qu'il est possible de faire quelque chose si l'on applique des stratégies susceptibles d'enthousiasmer les producteurs et productrices ruraux pour une idée et de susciter en eux l'esprit d'ambition. Si elle est impliquée dans une telle stratégie réfléchie et bien organisée, la simple production du foin peut se révéler comme indicateur ou activité initiatrice d'une nouvelle ère de développement.

CASE STUDY 3.
HAY IN ERZERUM PROVINCE - EASTERN TURKEY[1]

Along rivers and mountain streams, wherever water can be diverted onto land neither needed nor suitable for arable crops, a hay crop is taken, either from natural herbage or from sown lucerne. In some places, sainfoin (*Onobrychis viciifolia*) is grown on drier cultivated land. Lighter hay crops may be taken from dry hill slopes not required for grazing. The wild hay meadows vary considerably in quality: some are rich in natural legumes and forage grasses; others are in poor condition, especially where poor drainage and over-watering have lead to incursion of sedge (*Carex* spp.) rushes (*Juncus* spp.), reeds (*Phragmites* spp.) or mare's tail (*Equisetum* spp.). Heavy grazing in early spring has a detrimental effect on hay meadows, as does heavy stocking on lucerne and sainfoin aftermaths after the last cut of hay in autumn.

Lucerne and sainfoin have been grown in this part of Turkey for centuries - possibly even millennia. The indigenous ecotypes still widely used are generally long-lived; ten- to fifteen-year stands are common; stands of over twenty years are not uncommon. They are drought resistant and able to survive heavy grazing. There has been a shortage of seed of local ecotypes in recent years and the only seed available has been from farther west. The cultivar can be high yielding, but tends to be stemmy and shorter-lived (four to five years) and less tolerant of drought and grazing. Sainfoin is planted on land that cannot be irrigated, and commonly produces a hay crop for four to five years before exhaustion, although ten-year-old stands have been observed.

Wild meadows usually provide a single hay cut each year, although two are obtained from parts of the warmer northern valleys. In most of the province, lucerne usually gives two cuts, with three or four cuts made on favourable sites. Sainfoin generally gives a single cut. Vetches are sometimes sown in pure stand, but usually in mixture with barley, and may be cut for hay or grain.

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[1] Based on Fitzherbert, 1985.

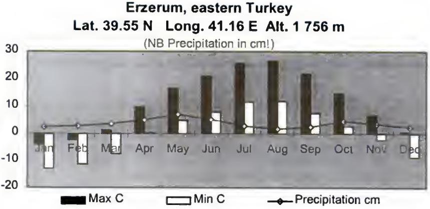

Figure 50. Temperatures and precipitation in Erzerum, Turkey

The different parts of the hay meadows, *chayir,* are almost invariably controlled by individual families as far as the right to make hay is concerned. There are, however, times of the year when the *chayir* is open to be grazed by all the village stock and not exclusively to those who have the hay rights. This is in early spring when stock are first brought out of their housing, usually April to mid-May. The date varies somewhat with place and season, but is usually respected by village custom and confirmed by local authorities. After this date, the *chayir* is declared out of bounds to grazing stock. In autumn, after the hay crop has been carted, the *chayir* is again open to communal grazing of the aftermath.

Stubbles (*aniz*) and fallow land (*nadiz*), are customarily treated in a similar manner: all stubbles are usually open to communal grazing, although the actual rights of cropping are invariably exclusive to individual families. The same also applies to lucerne aftermath after the last cut of hay and subsequent to the last irrigation. The reason for this custom is that stock are herded communally in most villages, although they are housed by their individual owners.

For grazing land, *mer'a,* some time between May 5th and 15th, according to location and village custom, the stock leave the *chayir* for the village *mer'a,* which is grazing land open to communal use by all the village stock. For villages with no access to alpine pastures, there is no alternative but to continue to graze the *mer'a* in the immediate vicinity of the village throughout the summer. There is a tendency to graze outwards from the centre as the season progresses. In some places the pasture is exhausted long before the stubbles and

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aftermaths become available in September to give a brief respite before winter. In Horasan district, however, the custom is to graze the perimeter of the *mer'a* at the start of the season; thereafter the stock graze gradually inwards, leaving the range closest to the village until last.

Haymaking

After the stock have left the *chayir* the meadows are irrigated once or twice before the hay is mown. Each family is responsible for flooding its own meadows, while the maintenance of irrigation canals and drainage ditches (if any) is the responsibility of all users. The *chayir* are mown from early July onwards; often the herbage is more mature than ideal to produce the best hay from a feeding point of view, but bulk is what most farmers are seeking. Hay is still mown and baled by hand throughout most of the Province; by men with scythes on the flatter land and sometimes by men and women with sickles on very steep slopes. It is carted from the field with ox and horse-drawn carts, or tractors if available. There is little mechanization of the hay crop as yet, except for some places in the central valleys where small, self-propelled mowers and a few mechanical balers are in use on the larger units. Few farmers can afford this sort of capital investment.

Traditional methods are well suited to local conditions: the weather on the whole is excellent for making hay. After mowing, the hay is left in its swathes for a day or so before being raked into windrows. It is then rolled into tight cylindrical bales bound round with skilfully spun lengths of grass rope. Bales of wild hay are generally larger than those of lucerne; they vary between 25 and 30 kg in weight but are of a size that can be loaded onto a cart by a man working on his own. Carting and stacking hay is laborious and often overlaps with the cereal harvest; the bales may lie out in the fields for weeks until the workers have time to cart them. Their cylindrical shape provides some protection against occasional thunder-storms that are a feature of the season. The traditional rolled bales are also particularly suited to making good lucerne hay, since valuable leaf can be lost from loose hay. After the hay has been carted, the fields are usually irrigated before stock are allowed to graze.

Siting of stacks

Throughout the central valleys it is customary in most villages to stack the hay either on top of or immediately beside the owner's house and stables. In the southern districts, hay is normally stacked one or two hundred metres from the village itself, in a communal rick-yard. There appears to be good reason for this:

the mainly Turkish-speaking villages of the central valleys seem to have lived in comparatively greater harmony with their neighbours than many of the villages in the southern districts, where a history of lawlessness and blood feud has been much commoner. In such a situation the danger of arson has been much greater, not only from without but from within the village community. Should a rival village set fire to your ricks at least your house will not burn down and should your neighbour have it in mind to burn your hay he will run the risk of burning his own at the same time. The final siting of the stack-yard in villages with a history of lawlessness is the responsibility of the local gendarmerie commandant.

Hay marketing

One of the most valuable crops in Erzerum province is hay. Not only as the most important winter feed, but as a crop to sell. This is true both of the hay from wild meadows and from sown crops. Some farmers in the central valleys grow hay as a commercial crop, and many other villagers sell hay if it is in excess of their own needs. Some also sell hay even when it is not in excess because they need the cash or because they feel that the cash value realized immediately by their crop is more use to them than the long-term return they might get by feeding it to their stock. Many villagers sell their hay and are prepared to keep their own animals, cattle in particular, on a mainly straw-based diet throughout the winter. The cattle in particular are slow-maturing at the best. The quickest and biggest profits are made by those who buy in three- to four-year-old animals from the mountain villages to fatten over a few months for slaughter, rather than by those who breed the animals in the first place. The villages have a need for cash in autumn to buy in provisions against the inevitability of being snowed in for days, if not weeks or even months on end.

Most of the hay is bought by merchants who transport it to Black Sea towns. There it is sold to small-scale farmers who produce hazel nuts and tea, but have very little forage. These small-scale farmers are comparatively prosperous, since they produce high-value crops; many have purchased Jersey or Jersey-type cattle. Although the merchants offer some price differential between legume as opposed to wild hay, there does not seem to be the same sort of differential between the best and worst grades of these two main categories.

CASE STUDY 4.
HAY DEVELOPMENT IN CHINA - 1. IRRIGATED HAY IN ALTAI KHAZAK PREFECTURE, XINJIANG (A FULLY TRANSHUMANT SYSTEM ADOPTING IRRIGATED HAY FOR WINTER USE)[1]

Altai Kazakh Prefecture lies between 44°59'N and 49°16'N, and 86°25'E and 90°31'E, at altitudes from 480 m at Fuhai to over 3 500 m, in the mountains. The fodder sites are below 800 m. The climate is continental; precipitation, mainly as snow, varies from under 100 mm/year in the plains to over 600 mm in the high pastures; winds are a problem. Cold waves, combined with high winds and snow, can cause heavy loss of stock. In the mountains, the weather is much colder and the higher pastures are open for less than three months each year. The animal industry is based on a system of transhumance; the division of grazing periods is shown in Table 18.

Table 18. Grazing periods in the Altai

Season	Duration
Spring	Early April to end of June - about 90 days
Summer	End of June to late September - about 83 days
Autumn	Mid-September to end of November - about 71 days
Winter	Late November to end of March - about 121 days

There are four great vegetation zones:

(i) **Alpine snow and rock**, of little use for grazing; the snow line is at about 3 500 m.

(ii) **The summer grazing lands,** which lie above 1 300 m and provide rich grazing for 75 to 95 days per year, these are the fattening pastures and, in season, are probably capable of carrying more stock.

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[1] Based on Li-Menglin, Yuang Bo-Hua & Suttie, 1996.

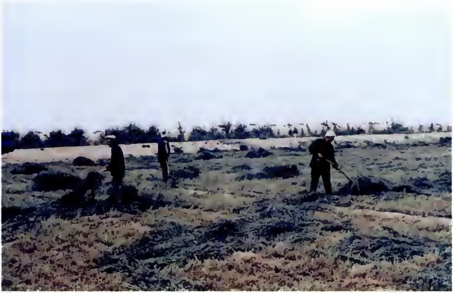
(iii) **Spring and autumn pastures,** which are also the transition routes, and they show serious signs of overgrazing. Due to lack of winter feed, herds linger on these pastures in autumn and go on to them too early in spring. The irrigated areas are in the drier, southern fringe of this zone.

(iv) **Winter pastures** in the plains, desert, low meadows and marshland, are totally inadequate for the number of stock carried. The provision of winter feed through irrigated hay production was identified as the most effective way of improving the overall production system and reducing pressure on the winter and transitional pastures. Desert grazing is controlled by snowfall: if there is no snow as a source of drinking water livestock cannot use the zone; sudden thaws or deep snow can be disastrous.

Haymaking is a traditional, albeit small-scale, activity. The very limited meadow hay along riversides is cut, by scythe or horse-drawn mower; some people always stayed behind in the plains in summer to do this work. Some mountain meadows are mown by the few communities that overwinter in the broader mountain valleys. The weakest part of the production system is winter feed.

To improve hay availability, the Animal Husbandry Bureau developed 25 000 ha of irrigated land on sandy-gravelly soils unsuited to arable cropping. Four-hectare units are managed by Kazakh herders' families; the herds follow their usual transhumance but some of the family stay behind during summer to irrigate the crops and make hay. The settlers are provided with loans so that they can have permanent houses as winter quarters. Social services - including medical facilities and schools - have also been made available, something which was inaccessible to families which had no fixed winter base. The rotation is four to six years of lucerne for hay, followed by a cleaning crop, then re-sown to lucerne. The effect of the forage on the following crop is very positive (see Table 19). The Kazakhs have no tradition of cultivation: herding, mostly on horseback, is the way of life for all. The development of the scheme has necessitated a lot of training, from senior technical staff to herders. It will be some time before the herdsmen become as proficient irrigators and agriculturists as the settled peoples of the Region.

Figure 51. Putting hay into cocks by hand (Altai, Xinjiang, China). In these hot, arid conditions the herbage must be cocked rapidly, otherwise there is serious leaf-loss



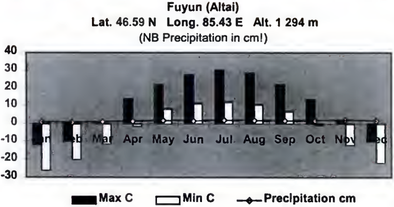


Figure 52. Temperatures and precipitation in Fuyun, Altai, Xinjiang

Weather during harvest is ideal for rapid haymaking, so simple methods give good results. Pilot areas of lucerne have given excellent yields of around 7 t/ha. Field plantings began long after the pilot areas, so only short-term yield figures are available. In the first three years of full field sowings, second-year crops averaged 4.1, 3.29 and 4.85 t/ha of hay. Only two harvests are taken per year, and the aftermath is grazed off once the herds return in November, once the herbage is killed by frost. With good organization and adequate fertilizer, a third cut could be attained and still leave adequate aftermath before the frosts. These yields are low, but well above the local average, and could be greatly increased by proper husbandry and fertilizer use. Outside the scheme, on old fields, grown mainly for seed production and not fertilized, average yields stabilized at about 2 t/ha of hay: this must be well below the real cost of providing water.

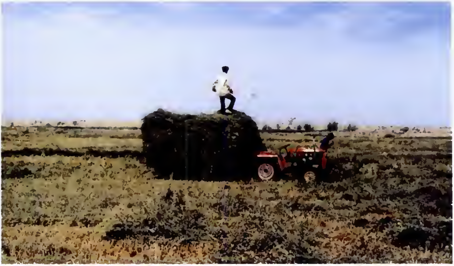
Table 19. Effect of lucerne on subsequent crop

Crop	**Before** (kg/ha)	**Following four years of lucerne** (kg/ha)
Wheat	2 250	4 500
Sunflower	1 050	1 800 - 2 250
Beet	22 500	33 750

The machinery hire service - with four-disc rotary mowers, tedders and pick-up balers - provided by the local authorities proved to be too costly. Mowing is now done either by contractors with small equipment - two-disc mowers or reciprocating blades - or by horse-drawn mowers. These tractors are privately owned by local farmers and, in addition to working their own areas, cut and windrow on contract (¥ 98/ha in 1994). The stubble height on the tractor-mown fields is more regular than in horse-mown fields. Trip-rakes are used for windrowing. The hay is windrowed after a few hours, made into small cocks, and carted about one day after mowing. The rapid curing followed by early, loose stacking gives good hay with little leaf-loss. The hay dries very quickly in the desert climate, and, at Fuhai, is often windrowed at mowing with mower and trip-rake in tandem behind a tractor; the hay is then put into small cocks with a fork and later hand-loaded onto horse carts. The hay is stored in low, loose stacks, and, because of the aridity of the climate, no thatching is required. Apart from the very outside of the stack, which is soon sun-bleached, the hay remains crisp and green for at least two years. The stacks are made within house compounds or earth-walled windbreaks to protect them from the very strong winds which periodically sweep the plains.

A local ecotype of lucerne, Beijiang, probably a hybrid between *M. sativa* and *M. falcata* (the latter is wild locally) is the main crop, with Laojiang broadleaf as a second. This very limited genetic base caused a lot of worry, and a wide range of "cold-tolerant" cultivars were introduced after a search of the world literature. Their early growth was most impressive compared to local controls, but none of the introductions survived the first winter. Winter conditions in Altai are very harsh and there is little or no snow in the irrigated areas to provide any protection. The Region must rely on its own genetic material and breeding skills to develop high-yielding, disease-resistant lucernes. The Department of Grassland Science of the Xinjiang August 1st Agricultural College is carrying out excellent work studying the local genetic resources of fodder plants, and especially of lucerne. They have bred and are multiplying improved lucernes. This crop is very important in both animal production and fertility maintenance throughout the Autonomous Region. These varieties could also be of great interest to other cold desert and semi-arid zones in continental climates, including central Asia and the higher parts of the Himalaya-Hindu Kush region.

Figure 53. Carting and stacking hay at Altai. Small tractors are becoming popular for haymaking



Localized waterlogging is a problem at some sites, either from a rising water table, often due to water from other irrigation areas, or wet patches due to poor field levelling. Much improvement of levelling is needed, and this is neither easy nor rapid by hand on stony soil, with limited labour and land frozen for months. In addition to tackling the root causes of the problem, forages tolerant of such conditions are being sought. Birdsfoot trefoil (*Lotus corniculatus*) is very promising. A wide range of cultivars have been tested and some are quite productive and hardy, having survived several winters. Within four years of the introduction of irrigation, several pasture legumes, characteristic of non-desert conditions, have appeared spontaneously in areas of higher fertility on moist sites, including *Lotus* spp., *Trifolium fragiferum, T. pratense* and *T. repens*. These occur nearby in grazed clearings in the riparian forests and their seed probably came in droppings.

Straw from the arable break in the rotation is stored and fed, but the overall winter ration is heavily dependent on lucerne - a rare case of winter feed being probably wastefully rich in protein. To date, no suitable grasses for haymaking have been identified and local preference is very much towards lucerne hay.

Changes in management systems to increase productivity, make better use of available feed and to minimize strain on the transition pastures, include:

- Lambing in February instead of April, which gives stronger lambs that will cross the transition pastures quicker, and produces a heavier lamb for September slaughter (traditional: 30 - 35 kg; new additional 7 - 10 kg (liveweight)). About 80% of the ewe lambs may be tupped in the first season. Good winter feeding and some shelter is necessary for this.
- September slaughtering of lambs for freezing, rather than over-wintering them for summer fattening, has been the policy since the early 1980s.

The effect of the improved supply of winter feed is already visible among the earlier settlers, both in flock size and in the condition of individual livestock. Any surplus winter feed is used for increasing their breeding herd through purchase of stock from needy neighbours - it is not usually sold. In addition to improving livestock production, this scheme has considerable social benefit, since the transhumant families now have access to education, in their winter quarters, during the long, severe winter, and to medical facilities, without losing the benefits of the transhumant system.

CASE STUDY 5.
HAY DEVELOPMENT IN CHINA - 2.
LEGUME HAY IN LIAONING (A FARMING COMMUNITY FATTENING LIVESTOCK)

Jianping County and Beipao City are in the northwestern part of Liaoning Province, immediately adjacent to Inner Mongolia, at a latitude of about 42°N. The production system is essentially crop-based, but stock are kept and store cattle, purchased in Inner Mongolia, are fattened. Local mining towns and export from nearby seaports to the big cities of eastern China make fat cattle attractive commercially. Cultivated fodder is cut manually and carried; grazing is forbidden. Lucerne (*Medicago sativa*) is mown twice yearly, in June and August; *Astragalus* mown once, in early September. In both cases, 10 - 15 cm of re-growth are necessary before the onset of the severe frosts.

Green or wilted herbage is carted to the homesteads in bundles to reduce leaf loss while drying. Often, the high-quality leaves are allowed to fall off the stems during drying; these are then carefully collected and used, powdered, for pig, poultry and rabbit feed; the dried stems are used for feeding ruminants. This indicates a sound appreciation, by the farmers, of the feeding quality and economic value of the different parts of the plant. *Astragalus*, in Beipao, is sometimes ensiled in deep, concrete-lined pits, which involves extra cost and labour, but is popular with specialized stock-rearing families, because it greatly increases the palatability of the bitter *Astragalus* and there is no waste after feeding.

Two types of fodder processing are practised:

- At village or specialized household level, hay is powdered by simple hammer-mills for inclusion in livestock rations. These mills also serve for grinding cereals.
- Jianping beet-sugar factory, which has no roots during April to October, makes pellets of dried lucerne and *Astragalus adsurgens* which are commercialized both within China and for export. Households sell surplus green fodder to processors, and it must be delivered and transformed into dried pellets within 24 hours.

Farmers are well aware of the many ways of using fodder products in animal feeding systems, for the various types of livestock, in combination with the other feed sources available: crop residues, forest grazing and cereals.

Hay yields are 2.5 - 3 t/h over the first three or four years, and then fall off sharply. *Astragalus* is shorter-lived than lucerne, and the stand thins out rapidly after the third season. These yields are reasonable for the rainfall, but could probably be improved, as could longevity, if an improved fertilizer regime were used. Currently, maintenance fertilizer is not usually applied.

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CASE STUDY 6.
HAY DEVELOPMENT IN CHINA - 3.
FODDER FOR ENVIRONMENTAL IMPROVEMENT ON THE LOESS PLATEAU (EROSION CONTROL AND DEVELOPMENT THROUGH FORESTRY AND PASTURE IN XIJI COUNTY, NINGXIA AUTONOMOUS REGION)

Xiji County is on the Loess Plateau in an area of typical continental climate, with an average summer maximum temperature of 32.6°C and a minimum of 5.3°C. The average rainfall 1937 - 1980 was 428 mm. Incidence and intensity of rainfall is highest in summer, leading to rapid run-off and erosion of topsoil. The elevation varies between 1 988 and 2 633 m. The county authorities initiated, in 1982, a series of interventions aimed primarily at stopping and reversing the trends of soil degradation, while increasing fodder, fuel and timber production. The interventions included:

- The conversion to forest or pasture of all crop land on slopes steeper than 15° or particularly exposed to erosion. On the remaining croplands, the government intensified its extension and training programme on increasing yields.
- On denuded, barren hills, the strategy was to convert separate areas on the upper and lower slopes to pasture and forest in order to increase the permanent cover and retain runoff. These plantings were combined with erosion-control measures.

For the marginal cropland, the conversion programme used local alfalfa (*Medicago sativa*), *Astragalus adsurgens*, and, in the early stages, *Melilotus* spp. On barren hills, alfalfa, *Astragalus adsurgens*, Sainfoin (*Onobrychis sativa*) and native wild-rye (*Elymus* spp.) were used, although mostly alfalfa.

The pasture specialist of the *ex post* evaluation mission reported:

"Large-scale planting of alfalfa on sloping, marginal land significantly contributed to the control of soil erosion and run-off through the provision of a permanent vegetation cover. The area planted rose by three times, from 9 370 ha in 1981 to 27 706 ha in 1990; the majority of alfalfa is still (1991) very productive and has more than 80 - 90% vegetative cover.

"Despite the high rate of failure of alfalfa and astragalus on the barren hills, there has been a positive effect of this activity on erosion control and run-off. The exclusion of livestock from these areas has allowed the native grass to grow back and the construction of mini-terraces on the contour has helped to arrest runoff.

"However the pasture and forestry conversion programme on the barren hills has had a negative effect on the remaining area of natural pasture (excluding the mountain grassland areas of the NE and NW), which is now much smaller than at the beginning of the project (natural grassland reduced from 57 789 ha at the onset of the project, to 16 794 ha during the project) and is showing the deleterious effects of a much higher density of grazing.

"The project also influenced strongly the direction taken by individual households to expand and diversify their opportunities for raising income from livestock. The initial impetus came from the introduction of the household responsibility system in 1982, which distributed livestock to households, but it was reinforced by the project's pasture conversion activities, which sharply increased the forage supply from 1985 onwards.

"With less grazing land available as a result of the project's pasture and forestry conversion activities, there has also been, post project, an intensive effort made by some villages to move towards a more intensive livestock production system. This has been reinforced by the increasing technical and financial support given by the Bureau of Animal Husbandry for the introduction from nearby counties and provinces of more productive and prolific native cattle and sheep breeds that can be yard-fed rather than grazed.

"Finally the greatly increased fodder supply developed through the project and the overall reduction in livestock numbers that has occurred, which is reflected in the rising offtake achieved between 1981 and 1990 (1.89% to 10.34% for cattle, and 8.8% to 20.5% for sheep and goats) has brought about a situation where feed supplies are broadly in balance with the numbers of livestock present.

"Pasture experience and lessons learnt

"1. Conversion of marginal lands to pasture using alfalfa has proved a sound innovation since it effectively controls erosion, raises soil fertility and greatly increases the availability of good quality fodder. Alfalfa has been grown successfully between widely-spaced rows of poplar trees on marginal agricultural land. However, both in the project area and similar areas, it will be important to integrate planting of alfalfa on marginal lands with ongoing programmes and plans for increasing the area of improved terraces on sloping marginal land.

"2. Conversion of barren hills to pasture utilizing mainly alfalfa and *Astragalus* was considered initially to be technically sound, since both species were thought to be adapted to the higher-elevation hilly areas. Subsequent experience has shown that both species were not adapted and, in addition, the costs of establishment were too high. Erosion was only partially controlled through the exclusion of stock, allowing some re-generation of native grass to take place. In similar areas, conversion of barren hills to pasture should not be attempted without adapted species being available, and using more cost-effective methods.

"3. The reduction in the area of barren hill grazing land has had a positive effect in forcing many villages in the project area to reduce their numbers of sheep and goats. This has led, especially post project, to an intensification of livestock production, where stock are now yard-fed and fattened over short periods to raise livestock income. Special attention should be given from the start of project activities to ensure that stratification and intensification of animal husbandry is fully supported by technical inputs, including intensification of fodder production.

"Recommendations

"Taking into account the present conditions in Xiji County post project, the level of achievement, and the lessons learnt, the following technical recommendations are made that are considered of special importance for improving the planning and technical input for future pasture components that may be introduced by new projects in nearby counties with a similar environment.

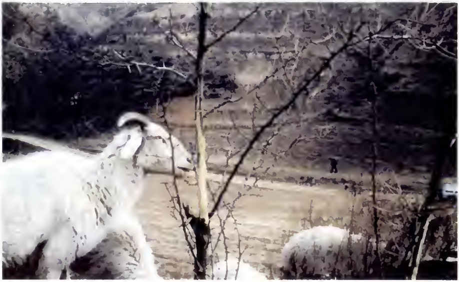
"1. In view of the harsh climate and the need to employ the most cost-effective treatments for renovating denuded, barren hills, consideration should be given to introducing simple hillside closure for 1 - 2 years, using guards, to allow re-generation of the natural vegetation to take place. After re-generation, these hillsides could be re-opened on a rotational basis for individual households to harvest the native grass, as directed by of the Chief of the Village Commission.

"2. Taking into account the current ongoing plans for greatly increasing the areas of improved terraces on sloping marginal land, both in Xiji County and other nearby counties, which takes up a large part of the available labour of farmers, much more attention needs to be given to introducing more intensive, short-term, high-yielding fodders, especially annual grasses and legumes, which can be grown in association or rotation with other agricultural crops on the improved terraces. This will require increased technical support from Grassland Stations to initiate the necessary fodder-crop trials on farmers' fields in order to find suitable species and varieties, and then to provide back-up extension support to get them into farm use.

"3. Taking into consideration the recent accelerated support now being given by the Bureau of Animal Husbandry to introduce more productive and prolific native cattle and sheep breeds in Xiji County that can be easily fattened in yards and do not require extensive grazing, more attention should be given in new projects to providing improved animal sheds, as well as better methods of feeding straw and crop by-products, and the conservation of fodders as hay or silage.

"4. Having regard to the shortage of crop land and the need to concentrate shelter belts and erosion-control plantations in strategic positions, which broadly protect the agricultural land below, more attention in new project areas needs to be given to designing and testing sylvi-pasture and agro-sylvi-pasture plantations that properly reflect the needs of the farmers for the short, medium and long terms. In view of the variability in performance in both forestry and pasture plantations established in Xiji County, which appears to have been greatly influenced by aspect, slope, exposure and other climatic and edaphic factors, the test sites need to be carefully chosen with these factors in mind."

Figure 54. Spring fodder deficit is severe on the Loess Plateau. This sheep is stripping bark from a sapling of *Robinia pseudacacia* (Shensi, China)



CASE STUDY 7.
HAY AND STRAW IN AFGHANISTAN (FODDER CONSERVATION FOR LONG WINTERS)

All of Afghanistan is arid to semi-arid, and in the uplands the winters are severe and long. Table 20 gives an indication of the range of climatic conditions encountered. Although holding sizes are very small and production is limited by availability of irrigation water, fodder, much of it for hay, is an important traditional crop. Cultivated fodder is grown in most farming systems, and haymaking is traditional throughout the country, mostly from irrigated forage legumes. Lucerne (*Medicago sativa*) and shaftal (*Trifolium resupinatum*) are the main crops. The preference for legumes has three reasons (apart from their growing very well there): they complement the coarse crop residues fed during winter; they do not require nitrogenous fertilizer; and they are recognized as improving soil fertility.

Table 20. Climatic data for some stations in Afghanistan

Station (Altitude (m))	**January temp. (°C)**		**July temp. (°C)**		**Precipitation**
	Max.	**Min.**	**Max.**	**Min.**	**(mm)**
		THE NORTH AND NORTHWEST			
Faizabad (1 200)	6.7	-4.7	33.4	16.0	321
Kunduz (433)	7.3	-2.4	33.7	23.1	349
Mazar-i-sharif (348)	9.1	-2.0	33.6	23.3	190
Herat (964)	10.4	-2.9	36.4	21.2	241
		CENTRAL HIGHLANDS			
Lal (2 800)	-3.4	-21.4	23.2	4.2	282
Kabul (1 791)	3.3	-7.4	32.2	14.0	276
Ghazni (2 183)	1.6	-10.7	30.3	13.9	292
		SOUTHERN, LOW STATIONS			
Farah (660)	13.9	0.2	42.3	24.3	77
Kandahar (1 010)	13.2	0.1	40.4	22.7	132
Khost (1 164)	13.4	-1.1	33.9	21.9	442
Jalalabad (580)	16.0	2.6	39.3	27.1	164

The fodder area was greatly reduced during the time when farm families were refugees, but now that the subsistence crops are being re-developed and household production stabilizing, fodder cultivation has re-started and is progressing rapidly. The traditional fodders are seen in most areas: more intensive concentrations of fodder are found in the areas supplying milk to urban areas. Seed markets visited in many parts of the country during the past three years have, in every case, had supplies of the local fodders, although home production and farmer-to-farmer exchange account for most of the seed used. Lucerne and shaftal for most of the country is locally produced, and climatic conditions are very favourable for seed production; Ghazni and Herat are both large producing areas. Lucerne seed was formerly grown for export, and now commercial production is re-established, seed is being sold in large quantities to Balochistan (Quetta) as well as for satisfying local needs. The proportion of fodder in the rotation varies, being between 5% and 10% according to local conditions and farmers' needs.

The report on FAO project TCP/AFG/4552 states

> "The main production and greatest need of fodder for cows is during summer, and oxen need to be in good condition for the spring cultivation, but the insufficient fodder supply during late winter is thought to be the biggest problem. In addition to the shortage of production due to limited land and water, it would be also important to know whether other reasons - like the lack of labour during haymaking or poor conservation techniques - contribute to the deficiency in winter."

The technical report (by O. Thieme) on the animal production element of the same project discusses fodder and hay:

"Livestock production in Afghanistan largely depends on grazing, but only about 40% of the area is suitable for grazing during winter (Yalçin, 1979). In higher elevations and mountains with low temperatures and long snow cover, indoor feeding is practised during winter for all livestock, and in the uplands and northern Afghanistan for large ruminants only. In the warmer areas of south and east Afghanistan, all livestock remain outside during the whole year. Supplementary feeding with fresh fodder crops, hay from pastures or fodder crops, agricultural by-products and concentrates during periods of scarcity or important production is, however, common in all areas. The most important fodder crops are lucerne (*Medicago sativa*), shaftal (*Trifolium resupinatum*) and, in the hotter areas of eastern Afghanistan, berseem (*Trifolium alexandrinum*). All three fodder crops are mainly fed to large ruminants. Berseem is given fresh, and lucerne and shaftal both fresh and as hay. Lucerne is also sold to other farmers, both fresh and as hay. It is grown as a perennial, but length of utilization varies between areas, from 2 to 7-8 years. Shaftal is planted as a second crop and mainly harvested in late spring. For Ghazni province, hay yields from four cuts of lucerne were reported as 7-9 t/ha and from shaftal as 2.5-3.5 t/ha (ASA, 1993). In some areas, up to 10% of the cultivated land was under fodder crops in the pre-war era (Grötzbach, 1990), and it seems that after the war fodder production has again resumed an important place in the farming system. Assuming that fodder crops are grown on 5% of the arable land, at least 1 million tons of hay-equivalent are produced.

"Even the smallest and poorest farmers keep at least one cow to provide their subsistence requirements for dairy products, but many farmers have more than one cow, and this is a common pattern all over the country (ASA, 1993). In all the areas visited during the mission, farmers showed a strong interest in increasing milk production from cattle. Compared to small ruminants, cattle have important benefits for milk production, especially for small farmers. Few numbers of cattle are easier to manage than sheep or goats; cattle have a longer lactation length; less seasonality of production; and they remain in the villages during the whole year, thus allowing the supply of fresh milk and dairy products to the whole family. In contrast, because of the common system of management, many sheep and goats move during the lactation period to summer pastures far from the villages, thus preventing the supply of fresh dairy products, especially to women and children. During the summer and spring seasons, fresh lucerne and/or clover (shaftal or berseem) is given to the stall-fed cows several times during the day, and in those areas where cows go out for grazing in the evening, at the homesteads. Important sources of winter feeding for cattle all over Afghanistan are cereal straw, hay from grasses or legumes, and maize stalks. Other sources of roughage, like leaves in Badakshan or camel-thorn in the northern Turkestan plains, have only regional importance. Great efforts are made to collect enough fodder especially in those areas with a long winter period like Badakshan or the Hazarajat, and large stacks of hay are stored on top of the cattle houses (Centlivres and Centlivres-Demont, 1977). Very often, wheat straw is mixed with legume hay before feeding. Bouy and Dasniere (1994) calculated, for villages in Badakshan, an average availability of 1 t of straw and 200 kg of legume hay per animal unit (300 kg), which was sufficient for the indoor feeding period of about 110 days. In contrast, information collected from farmers in Ghazni and from Kandahar (ASA, 1993) show that many farmers have to purchase straw and/or hay to provide sufficient roughage for their cattle during winter. Milking cows and working oxen during winter usually also receive a supplementation with concentrates like cotton seed cake, maize or barley grain. Information about the daily amount offered range from 250 - 400 g in Ghazni and Khost (Barker and Rahmani, 1994; Halimi, 1995) to 1.8 kg in Sar-i-pol and 2.5 kg in Balkh (Pers. obs., 1996; ASA, 1993).

"During winter, most small ruminants of villagers are housed during the night and during bad weather. Hay, straw, leaves, different local types of roughage and concentrates are given as supplementary feeding during this period. In Nuristan, the most important roughage for goats are leaves from the evergreen oak trees (Edelberg and Jones, 1979). The actual amount of feed given and the length of the feeding period depend on the region and the weather conditions. A supplementation of concentrates, with 200-450 g of maize or barley for two months seems to be a common practice (ASA, 1993) and McArthur (1980) found that the local practice of giving these concentrates before lambing only to weak animals was more economical than supply to the whole flock.

"Crop residues

These are a major source of feed in sedentary production systems. Wheat is the main winter crop, although some barley is grown. Maize and (locally) rice are the summer cereals. Haulms from pulses including grams (*Vigna* spp. *mash*), lentil, pea and groundnut are used as fodder. Cotton sticks may be grazed or taken to the homestead as feed and firewood. Local wheat threshing methods chaff the straw, which can then be stored and fed easily. Straw treatment with urea has been demonstrated, but in many areas there is a global scarcity of dry matter, so treatments which increase feed intake are problematical. Urea/molasses block supplementation of straw-based feed in winter has had very promising results, and seems likely to become popular in some areas".

Much of the straw, and chaffed legume haulms, is stored in mud-covered clamps. In areas where supply exceeds requirements (or in case of need for ready cash), crop residues are sold, mainly to Kuchis, but some feed-scarce villages purchase straw for winter use and transport it over long distances.

Hay and fodder crops

Lucerne (*Medicago sativa*) (*rishka*) is the most widespread and popular fodder and is cultivated from the lowest and hottest to the highest and coolest zones in all provinces of the country. Local ecotypes are used. Nearly all the crop is irrigated, so one of the criteria when choosing between lucerne and clover as a fodder is always the availability of water throughout the entire growing season - much of the irrigation is seasonal. The crop is often sown under wheat, and very high seed rates of up to 60 kg/ha are used. Seed quality is often mediocre; farm-grown seed or seed exchanged with neighbours is usual. In areas of specialized cultivation, close to big towns where lucerne is sold as a cash crop, it may be direct sown or sown with a temporary nurse crop for shade, especially in the hot season; millet (*Panicum miliaceum*) is sometimes used as a summer nurse crop near Kandahar. Spring sowing is as successful as autumn, but, since most is sown with wheat, broadcast autumn sowing is general. The crop is established with the intention of its lasting for many years - ten is often claimed - and local ecotypes certainly persist well, although their best performance is in the first five years. The number of cuts depends on the local climate; in low-altitude areas, six to eight cuts are possible where water is adequate; in the high areas, over 2 000 m, three cuts are usual.

Table 21. Livestock numbers in Afghanistan, 1967-1995 ('000s)

	1967(1)	**1981(1)**	**1991(2)**	**Resident farmers 1995(3)**	**Kuchis 1995(3)**
Cattle	3 633	3 750	4 049	3 495	198
Sheep	21 455	18 900	18 688	15 504	6 508
Goats	3 187	2 900	5 458	3 472	
Horses	403	400	245	167	200
Donkeys	1 328	1 300	1 131	872	147
Camels	299	265	80	101	176

Sources: (1) Central Statistics Office, *Afghan Agriculture in Figures* (1978); Statistical Year Book 1360 (1983); (cited after Grötzbach, 1990). (2) Own estimates using data from: The Swedish Committee for Afghanistan; The Agricultural Survey of Afghanistan, 14th Report, 1991 Survey. (3) Own estimates using data from the headcount in 1995, organized by FAO/UNDP Project AFG/93/004.

Table 22. Crop areas in Afghanistan, 1997 - 1998

Crop	**Area** (million ha)	**Production** (t)	**Yield** (t/ha)
Wheat	2.35	2.65	1.13
Maize	0.48	0.76	1.58
Rice	0.21	0.40	1.91
Barley	0.31	0.30	0.97
Others	0.04	0.04	0.81
Total/Mean	3.39	4.15	1.22

Shaftal or Persian clover (*Trifolium resupinatum*) is the second of Afghanistan's major fodders. It is used in rotations and also in situations where perennial irrigation is not available for lucerne. In warm zones with two-season cropping, e.g., Khost, it is preferred to lucerne since the shaftal is harvested in time for summer crops to be sown; it is sown September-October and harvest is over in May. In high altitude areas, where the clover is dormant under snow for months, harvest does not begin until May, and three cuts are taken up to August - the last cut may be harvested for seed. In all areas, it is autumn-sown for spring and summer use. In the higher, cooler areas it may also be grown as a summer catch crop after winter cereals; in some places, shaftal is sown in standing wheat at the time of the last irrigation. Two hay cuts and a seed cut are frequently taken from autumn-sown crops. A precocious cut of very young leaves may also be made for drying as a table vegetable. Shaftal is successfully made into hay. There are said to be several landraces. The standard of shaftal fields seen shows a superior crop to that seen in Pakistan, so some selection by farmers may occur. Most of the shaftal sown in its traditional areas is from locally-grown seed that has had little or no quality control, and in some places farmers use very high seed rates. This should not be difficult to improve, as it is a free seeder. Landraces in Afghanistan, where shaftal is a very important hay plant, are much superior to ordinary Pakistan material, especially in Ghazni and Herat Provinces.

Egyptian clover or berseem (*Trifolium alexandrinum*) is a crop of recent introduction, via Pakistan. It is grown in some of the lower areas, such as Khost and Ningarhar, where the winters are sufficiently mild; it only withstands light frost. Cultivation methods are similar to those for shaftal, but it is usually sown directly in early September, possibly mixed with some mustard. If sown early, berseem, unlike shaftal, has rapid early growth and one or more cuts can be taken before growth stops temporarily due to cold weather. A further four or five cuts can be taken in spring. It is, in suitable climates, more productive than shaftal and produces in autumn and early winter as well as during the spring peak. It is not as popular as shaftal and is mainly used as green feed, and is not nearly as easy to make into hay as lucerne or shaftal. It is not suitable for use as a table vegetable. It is unlikely that berseem will replace shaftal in Afghan agriculture in the manner it did in the warmer conditions of Pakistan and northern India.

Other fodders, such as vetches (*Vicia* spp.), are widely grown, often as a summer catch crop, but their volume is nowhere near as important as that of lucerne and clover. Chickling vetch (*Lathyrus sativus*) is cultivated in the very high altitude areas as both a fodder and a pulse. No fodder grasses are cultivated, although maize thinnings are used in all areas where the crop is grown, and green wheat may be cut as fodder in times of scarcity.

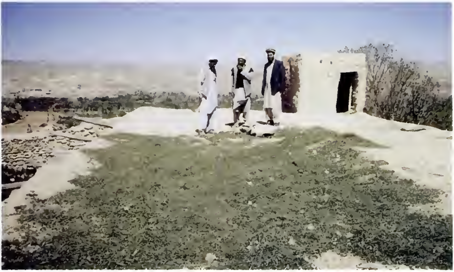
Traditional haymaking techniques

Haymaking is almost entirely manual; mowing is generally by sickle, although the scythe is known. The common traditional sickle is smooth-bladed with a relatively straight blade set on a long metal neck attached to a wooden handle; the handle may have a slight hook at its extremity; the sickle is wielded with a scythe-like motion but using only one hand. A typical sickle appears in Figure 55.

Hay from cultivated forage is nearly all lucerne and shaftal. They are both excellent hay crops, but the greatest problem in making hay in the hot and dry summers is avoiding leaf-loss through shattering. Traditional systems take this into account. The crop is mown and left to wilt in the swath until limp, and it is removed from the field and dried elsewhere before there is danger of leaf-loss.

The wilted herbage may be tied into small trusses which are set on the bunds to dry; this also frees the field and allows re-growth with a minimum of shading from cut herbage and traffic during other haymaking operations. The trusses are turned periodically and, when they are judged sufficiently dry, are stacked loosely for further field drying, before final transport and storage.

Figure 55. Shaftal drying on a roof (Ghazni, Afghanistan)



Excellent hay is produced in this way and the leaves are kept within the trusses. These processes are shown in Figures 6 and 7. After wilting, the forage may be carried to the homestead and dried out of reach of livestock, often on the roof. Any fallen leaves will be swept up and saved (see Figure 55). Shaftal is sometimes made into long, rope-like trusses, which are hung over the sunny sides of houses for initial drying and then finished on the roof. Hay storage is often under cover.

Hay from natural pasture

There is little natural vegetation suited to haymaking, although in the eastern areas near the Pakistan border, some hillsides produce enough vegetation to be worth mowing. The grasses are mostly unpalatable while green (although the inflorescences are eaten by small stock), but the dried grass is eaten.

Hay from shrubs

On the northern plains near Balkh, an unusual hay is made from the self-regenerating camel thorn shrub (*Alhagi* sp.) which appears in almost pure stand during the fallow years of wheat cropping. There is not enough water to irrigate all the available land, so wheat is rotated with fallow. The thorns are mown in late autumn, dried in the field, bundled and stored at the homesteads, then fed to camels and goats during winter. Uneaten stems are used as fuel. Analyses of camel-thorn hay from neighbouring areas of Pakistan are given in Table 23.

Table 23. Analysis of camel-thorn, *Alhagi* sp., from Balochistan

FEED	Crude protein	Crude fibre	Crude fat	Ash
Whole plant, July 1994	10.20	28.27	2.42	7.48
Leaves and thorns, winter stores, November 1994	10.56	-	-	10.79
Seed only, November 1994	12.62	-	-	-

Data provided by P. O'Donovan and T.J. Barker.

CASE STUDY 8. HAY FROM NATURAL PASTURE IN MONGOLIA (THE CHANGE FROM COOPERATIVE TO PRIVATE STOCK-REARING IN A PURELY PASTORAL ECONOMY)

The following notes are from ongoing work supported by FAO and from mission reports covering, first, in 1989-90, the period when the entire livestock production of the Republic was managed by immense cooperatives (with a few State Farms), and, second, the final visit in 1995, when the centralized system had been disbanded and the private, family-group system was in the process of re-establishing itself.

The changeover has not been simple and there are many problems still to be resolved throughout the pastoral organization and economy. Insofar as haymaking is concerned, it has changed from a large, highly mechanized and subsidized, state-managed operation, to a return to old, hand and draught-animal systems managed at the level of the family group and smallest administrative unit.

Mongolia is one of the few countries where the economy is almost entirely pastoral; of a total land area of 1 500 000 km^2, some 1 210 000 km^2 (80%) is classed as natural pasture; 150 000 km^2 is forest and, in 1989, 130 000 km^2 was arable. The climate is severely continental, with a windy spring with variable weather (spring rain is especially valuable to get the pasture growth started before the summer rains); a warm summer, when rain falls in the earlier part; a cool autumn; and a cold winter, with temperatures as low as -30°C. Rainfall is low; the largest grazing area - the steppe and mountain-and-steppe - get between 200 mm and 300 mm annually, and only the northern zone gets over 300 mm. The growing season varies a little with altitude, but it is always short, of the general order of 90 - 100 days.

Haymaking in the cooperative era

In 1989 and 1990, near the end of the cooperative period, the situation was described as follows:

"Hay from natural pasture is by far the most important source of winter feed for Mongolia; it is estimated that some 20 000 km^2 are cut annually for hay. Most of this is mechanized production by cooperatives and state farms. North Mongolia, the better-watered part of the country, is the most favoured for hay production. Methods of increasing production have been studied over many years, but results are not very encouraging: fertilizer has a highly positive effect, rain permitting, but because of unreliable rainfall and the high cost of fertilizer - all of which has to be imported - it is considered totally uneconomic. A gradual decrease in hay yields over time occurs when the same field is cut year after year: research indicates that a rotation of the cutting dates on the same plot will, after several years, lead to an improvement in hay yield, but so far the increase is only around 10%.

"Hay production on cooperatives is generally carried out by salaried staff. Special areas are set aside for hay production, which is mechanized (although families may make hay by hand for personal livestock). Each brigade has a store of hay allocated to it at harvest time and a central reserve is held by the cooperative; hay produced cooperatively is only for the feeding of cooperative stock and should not be given to family animals. Hay production is inadequate for the calculated needs to supplement the feed the stock get off the range, and is said to attain only 30% of the theoretical requirements. There is insufficient good hay land in much of the steppe and desert-and-steppe area, so cooperatives frequently travel to north Mongolia to make hay, paying those cooperatives from which they get the cutting rights. Hay is usually made in August/September; yields are of the order of 1.2 t/ha of made hay.

"While the livestock gain most of their feed from the pasture throughout the year, the grass dries off from mid-August and thereafter they have to survive on standing hay until mid-May. After October, feed is deficient in both quantity and quality, but the indigenous breeds survive: the sheep are all fat-tailed or fat-rumped breeds and this reserve helps them as a source of energy during winter. In order to avoid excessive winter losses, some hay is fed to weaker groups of stock to increase their chances of survival. Considerable weight loss occurs in winter and, although ensuing weight gain is said to be rapid in spring, especially in sheep, the improvement of winter feeding is one of the more likely ways to get an increase in production from the national herd.

"Snowfall in the steppe is generally light. Some snow is desirable as a source of winter water for stock and to encourage spring pasture growth. Deep falls do occur, and can have a disastrous effect on the livestock, since they cannot reach short grass through deep snow. Hay must be given to livestock in such conditions, sometimes having to be transported by air.

"Subsidized hay transport was still going on in 1990. It had been the wettest season for thirty or forty years, so grass growth was excellent, the almost daily rain and cloud throughout August, however, caused serious delays in haymaking and if it continued it might also affect the grain harvest. The South Gobi Aimak, with its headquarters at Dalandzagad, had a total area of 165 000 km^2 and a human population of 41 000; the average precipitation is 70 - 132 mm/year and its distribution is very irregular. Animal husbandry is the main industry of the area and almost the only source of livelihood for the rural population. It is the first *Aimak* (Province) in the country for goat and camel production and exports some 7 000 t of camel wool and 130 t of cashmere annually; livestock numbers are: goats 400 000, sheep 290 000, camels 130 000, horses 70 000, cattle 20 000, and some pigs and poultry. The dry season is long and severe, and droughts are common; although the livestock are well adapted to local conditions and the standard of husbandry skills high, spring and winter feeding of the herds is a serious problem. Annual imports of hay and fodder varied between 30 000 and 40 000 t/year, most of which had to be transported from 1 000 km away. Previously, the cost of transporting the fodder was borne by Central Government, but with the ongoing re-organization of the agricultural economy, this might not continue. In a region of 70 - 130 mm of rain there is very little potential for increasing the productivity of the natural pasture and even less of solving the seasonal feed deficit from the grazing lands."

Haymaking after de-collectivization

A visit in 1995 to Ikh Tamir *sum* (District) in Arkhangai Aimak (in the mountain-and-steppe zone) showed a very changed situation: the cooperatives had been dissolved; the traditional family group system was re-emerging; centrally managed haymaking had ceased; and the herders were sorting the situation out gradually. The re-organization of the pastoral industry privatized the livestock but did not tackle the problem of land rights, so Mongolia has the unfortunate combination of private herds on public land. Arkhangai Aimak is in the central area of the Khangai mountains, the aimak headquarters, Tsetserleg, is about 500 km west of Ulan Bator. Half of the route is an unstructured track which is impassable after rain. Its latitude is roughly 47°30'N at 103°15'E. It covers a range of ecological zones, including high mountain, mountain steppe and steppe zones (See Table 24). The elevation is 1 700-1 850 m; mean precipitation 363 mm, of which 80% falls in the period May to August; mean maximum temperature in August is around 16.0°C falling to -16.0°C in the December to February period, with absolute maximum and minimum temperatures of +34.5°C and -36.5°C. The Province covers 55 300 km^2, of which 41 000 km^2 is pasture, 540 km^2 hay and 8 645 km^2 forest. The steppe zone, in the east of the province, has the mildest climate: mean January temperature is -16°C (absolute minimum -38°C) and July mean is 17.5°C (absolute maximum 35°), with 98 - 125 frost-free days. The main ecological zones are shown in Table 24.

Table 24. The ecological zones of Arkhangai grazing lands

Ecological zone	**Altitude range** (m)	**Rainfall** (mm)	**Frost-free days**
Steppe and mountain steppe	1 300 - 1 700	315 - 360	130 - 165
Mountain steppe	1 700 - 1 900	370 - 480	90 - 150
Mid-mountain	1 900 -2 350	440 - 470	70 - 140
High mountain	2 350 - 2 500	450 - 550	50 - 120

The high mountains are summer yak pasture, which is not really accessible to other species, although it can be used for horses. Because of the more humid conditions in the high zone, small ruminants suffer from foot rot if herded there. The area is well watered by mountain streams and rivers; water for livestock is not generally a problem in the warmer months, although it may be locally. In winter, stock must be watered by cutting through ice to water, or by eating snow, with a consequent extra energy requirement. Forests are common in the mountain and mountain-and-steppe zones: *Larix*, *Betula* and aspen in mountain forests; poplar and willow in riparian forests. Timber and firewood are readily available in much of the aimak. Generally the sward is dominated by grasses, but in areas of favoured moisture status, broad-leaved species, including legumes, are common. In the higher areas, Cyperaceae are frequent: the dominant pasture in the high mountains is a *Carex-Kobresia* community.

Hay from natural pasture will remain the main, probably the only, conserved fodder throughout the aimak. At present, hay lands are not allocated to herders, so cutting is unregulated and competitive; maintenance or improvement of hay land is therefore possible. The area of hay land is inadequate for the aimak's needs, and yields are very low. The growing season is short throughout the project area and scarcity of winter and spring feed is a major constraint to intensification of livestock production. Winter feed, in addition to being scarce, is of low quality. In spring the stock graze the young growth before the plants have had time to gather strength, and probably further weaken the vegetation. Herders are loath to give supplementary feed except to special classes of stock (milking and pregnant animals, riding horses) because fed animals tend to graze less and come home early to wait for feed.

Prior to collectivization, herders followed well-tried, traditional grazing patterns and were well aware of the principles of seasonal grazing according to pasture suitability. Traditional, informal grazing rights to specific areas throughout the transhumance system were recognized: the lords intervened to regulate grazing systems to ensure sustainability. The collective period led to an artificial concentration of animals.

The work in Arkhangai was situated in Ihk Tamir sum, at the High Mountain Research Station, which concentrates on montane pasture and livestock management questions, including yaks in some areas, and there were some ill-conceived attempts at specialization and establishment of monospecific units. The inherent flaws in such systems were recognized and considerable changes to rationalize grazing practices were made in the 1980s. At the same time, large investments in infrastructure (communications, schools, health care) drew herders to concentrate close by *sum* and *negdel* headquarters, leaving the further grazing lands under-used. To palliate this, mobile butter-making units were organized to facilitate seasonal utilization of the high pastures. Haymaking and crop production were undertaken by specialized brigades and élite breeding herds provided sires (and a monitoring service) to upgrade the local landraces. In the early 1990s, the *negdels* were disbanded, along with the specialized production brigades, and livestock were allocated to private individuals, but without any parallel allocation of responsibility for grazing and hay land.

Previously, haymaking, on both farms and natural hay-fields, was done collectively and mechanized. The equipment was distributed on de-collectivization, and functioning sets of haymaking machinery are now rare. The large machinery would not have been suitable for present conditions. Now almost all of the hay is hand-mown from natural stands. Yields are very low, 600 - 700 kg/ha with 18% moisture, and haymaking is slow and laborious. Although yields are very strongly affected by rainfall, it is likely that most hay fields are declining in yield and quality since they have been mown yearly over a long period without rest, manure or fertilizer. The High Mountain Research Station has been working on improvement of hay yields from natural stands, looking at variation in cutting dates, dung and fertilizer application, irrigation, etc. Traditional water-spreading methods practised in the mountain-and-steppe involve sporadic diversion of spring water in winter to develop ice-sheets over hay land. The ice sheets will then melt at the onset of the growing season.

Grazing on exposed and sheltered hills is reserved for the winter; autumn and spring grazing takes place on the slopes leading to the higher areas, and on tree covered areas which will be inaccessible in winter because of deeper snow.

Haymaking "fields" (and potential sites), often meadows, lie in these areas in sheltered spots along streams and where natural drainage lines favour a concentration of moisture, one of the keys to good grass growth. These areas would be grazed early in spring and then left for haymaking (and later autumn and winter feed), as the livestock (horses, goats, sheep, cattle and yak) are moved down to lower elevations.

Haymaking has been carried out for a very long time. Historically each herder was entitled to use certain land, where hay had been cut for many years. After privatization, however, every hayfield has become a focus of disputes between individual herders and members within social groups, as well as people from neighbouring societies. Also, repeated cutting, which has been done for the past few decades, has led to a serious decline in the natural productivity of hay fields and there is no sign, at present, that herders will invest in their improvement.

Figure 56. Horses form a large part of Mongolia's livestock and are used for milk and meat, as well as transport. The short (3-4 months) growing season precludes sown fodder, and the livestock survive the long winters through foraging, with perhaps a little natural hay in emergencies (Kharhorin, Mongolia)

Natural hay fields have usually been mown for a long time, so stones and obstructions have largely been eliminated. Further study is required on sources of animal drawn equipment - mowers and trip-rakes (carts are available) - as well as on how to finance their acquisition and organize their management. Ways of raising yields will also have to be investigated if haymaking is to be improved. Haymaking costs, other than cartage and stacking, are proportional to the area dealt with rather than the quantity of hay made.

The botanical composition of the hayfields varies, of course, according to site. In the mountain steppe: *Leymus chinensis, Stipa krilovii, Festuca leneni* and *Koeleria cristata* are the main grasses; and *Carex duriscula; Artemisia lacenata, A. glauca, A. commutata* and *Plantago adpressi* are the main herbs. In a riparian meadow: *Leymus chinensis, Koeleria cristata* and *Agropyron cristatum; Carex pediformis; Artemisia lacenata, Potentilla tanacetifolium, P. anserinum, Galium verum* and *Plantago adpressa.* In a rainfed mountain meadow: *Agropyron cristatum, Poa subfastigata, Festuca* sp.; *Carex pediformis;* and *Artemisia lacenata, A. dracunculus, A. glauca, Thalictrum simplex* and *Galium verum.* A mountain meadow on a north slope: *Bromus inermis, Calamagrostis epidois, Elymus turczanovii* and *Stipa baicalensis;* and *Carex pediformis, Artemisia lacenata, Geranium pratensis* and *Galium boreale.* The overall proportion of plant types in hay is herbs (considered to have poor feeding value), 39 - 58%; *Carex,* 11 - 22%; grasses, 20 - 37%; and legumes, 6 - 18%.

Haymaking trials and demonstrations were established in Ikh Tamir district in 1996. Initial trials focused on different rates of dung and their effects, with 50 t/ha being selected as the rate to be used in trials with ice irrigation and mineral fertilizer (80-90 kg/ha of NP fertilizer). Ice irrigation, dung and mineral fertilizer all increased the number of plants per square metre, the length of vegetative shoots and dry matter production. Differences were particularly significant in 1996, but less so in the dry year 1997: in 1997, percentage increases ranged from 253% with ice irrigation to 407% with ice irrigation plus dung, and 707% with ice irrigation and mineral fertilizer. The percentage of grass plants increased on the treated plots while the percentage of sedges fell. A simple dung-spreading cart was constructed in an effort to make dung spreading less arduous. Land ownership (all land was currently state owned) and continued access to land remained key questions. Although families had traditional grazing rights (but not ownership) any move to invest time and resources to increase soil fertility and hay production brings with it the need for some security of access to that area of land for a reasonable period of time.

CASE STUDY 9. HAY AND CROP RESIDUES IN PAKISTAN[1] - 1. HAY AND FODDER IN MIXED SYSTEMS AND FOR SALE

Livestock production forms an integral part of almost all farming systems. Small-scale farm livestock production, however, revolves around subsistence, although surplus milk may be sold. The vast majority of dairy stock are in the intensively-cultivated irrigated tracts where there is no natural pasture; stock are kept around the homestead and stall-fed on crop residues, fodder and some concentrates. Fodder is important in all districts for on-farm livestock, and often as a cash-crop for sale, fresh or dried, to supply urban dairies; it accounts for 14.6% of the total crop area.

The bulk of agriculture in Pakistan is on the great irrigated plains of the Punjab, the North West Frontier Province (NWFP) and Sindh, with ruminants fed almost entirely from the produce of arable land, there being no grazing except along a few river valleys and some areas of semi-desert. In the plains, the growing season covers nine to ten months of the year and green feed is available year-round to supplement crop residues. In the semi deserts of Balochistan and the lands behind the Himalaya, there is seasonal movement of stock to grazing lands, usually to higher altitudes in summer, and fodder is produced where irrigation is available.

Commercial herds are few in rural areas, but are very important in the peri-urban zones (see Table 25) around big cities (Karachi, Lahore, Hyderabad, Gujranwala, Islamabad/Rawalpindi, Faisalabad, Peshawar and Quetta). The feed supplied to these units is trucked in, and some is produced over 300 km away (e.g., from Hyderabad and beyond to Karachi; from Kasur and Renala to Islamabad). Cities in the irrigated tracts find supplies relatively close, but Karachi and Islamabad in particular have to haul feed over long distances. Buffalo predominate in the town herds of Punjab, Sindh and NWFP. In Quetta, Balochistan, only half of the urban herd is buffalo, due to several factors, including the scarcity of water. Afghan refugees brought excellent pure and cross-bred Friesian cattle to Quetta and greatly increased the local dairymen's interest in cows. Milk price is based on butterfat content, so with buffalo at over 6.5% and Sahiwal cattle averaging 5.5%, the buffalo is popular.

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[1] Based on material from Dr Sadaqat, S. Hanjira and Dost Mohammed.

Table 25. Feed sources for dairy stock(1) around some Pakistan cities

CITY	Dairy herd (head)	Source districts	Distance
Lahore	125 000	Kasur, Sheikhupura are major green feed suppliers. Dry roughages from Gujranwala Division.	< 100 km
Karachi	150 000	Green feed from Hyderabad, Thatha and adjoining areas. Dry roughages from Central Punjab, Lower Sindh.	> 300 km maximum green
Gujranwala	105 000	Surrounding area	-
Islamabad - Rawalpindi	Unknown	Dry roughages from Gujranwala and Sargodha divisions. Hay from adjoining villages. Green feed from Hafizabad and very scattered, as far as Kasur;	> 350 km maximum (Kasur)
Hyderabad	Unknown	Adjoining areas and lower Sindh	
Peshawar	60 000	Surrounding areas of Charsada and Mardan. Wheat straw from Punjab. Lots of sugar-beet pulp available.	
Faisalabad	100 000	Surrounding area	
Quetta	50 000	Surrounding area and Sindh.	

Note: (1) Does not include draught stock (donkeys, horses, camels and oxen).

Over the years, transport costs have risen substantially. This has lead to conservation. Data is not available, but huge quantities of oats are now regularly converted to excellent hay and transported over long distances. The rapid rise in the popularity of oats over the past fifteen years has been due to the introduction of high-yielding varieties which give several cuts, such as cvs Scott and PD2-LV65. In the 1950s and 1960s, oats were grown for fodder, but mainly to make hay for horses, which at that time was the main transport animal in rural as well as urban areas; the *tonga* was used for intra-city transport and in the rural areas for access to town markets. In the 1970s and 1980s, motor vehicles replaced most of the horses, but in the late 1980s the dairy industry began to expand, and more and more milk marketing outlets became available. A large number of milk processing units were installed. The expanding urban population provided a lucrative milk market, dairy stock were better managed and fed. Fodder production became an important activity, especially near big towns. The oat crop developed to replace the poor quality wheat and rice straw which had formed the basis of the ration. Multi-cut varieties of oat were developed by the Pakistan

Agricultural Research Council, and the Farming Systems Research Programme in Punjab did much of the initial popularization and seed bulking of oats. The old single-cut varieties have now been replaced by multi-cut forms. These oats are good producers in the cold weather when other green feed is scarce, and are replacing the fodder brassicas, which were formerly used in the winter gap.

Commercial hay making from lucerne and berseem has also started in pockets. In Gilgit and the Quetta Valley, lucerne hay is sold where surplus to farm requirements. In the Quetta Valley, where small dairy units are coming up fast, 40-50 t of lucerne hay is marketed at a price of about PRs 2.5/kg (US$ 1 = PRs 40 at the time of writing) from around the city in September to October. Substantial quantities of dried stalks (maize, sorghum, millets) are sold to cities and within the production zones, particularly in the rainfed areas (parts of Rawalpindi, Jhelum, Chakwal, Attock, Mianwali, etc.).

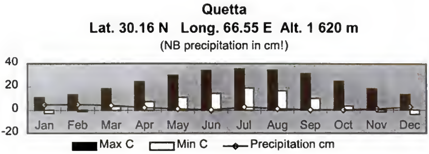

Figure 57. Temperatures and rainfall in Quetta, Pakistan

Fodder yields are low in comparison to their potential, with 20 t/ha a recent estimate. Although greatly improved technology and varieties are available, these have been slow to reach the small-scale farms that account for most fodder production, and seed production has lagged behind plant breeding and introduction. Recent medium-scale, on-farm work has indicated that yields can be increased two or threefold using available improved varieties and appropriate agronomic techniques. In an area where land and irrigation water are the main limiting factors to increasing fodder, intensification is the only way to meet the country's needs for more livestock products and, therefore, of fodder.

Dried fodder

Extensive drying is carried out in the rainfed districts (Sialkot, Wazirabad, Gujrat, Jhleum, Rawalpindi, Attock, Mianwali, D.I. Khan). The system is also prevalent in the Northern Areas and parts of Sindh. The crops used for drying are sorghum, millets, maize and oats. In the rainfed areas of Punjab, parts of NWFP, Sindh and lower Balochistan, it is customary to convert stalks of sorghum, maize and millet into *kadbi*, this material is used after chopping and mixing with some green fodder (see Table 26) Sometimes part of the seed heads or cobs are left on the stalks to improve their feeding value. In parts of Balochistan, a thin-stalked maize with low cob yield is grown as fodder and the cobs are left on. The *kadbi* is made by drying the cut material thoroughly, then stacking it upright. The stacks are sometimes plastered with mud. Part of the *kadbi* is sold to urban dairies.

Rice straw is a major, albeit poor, feed. It is usually stacked on field edges or where stock are kept; it is often fed *ad libitum*; it is not chaffed.

Wheat straw is a major and very popular feed, always in the chaffed form. In recent years, baling units have been installed in central Punjab. The bales are transported to all major cities. Traditionally the chopped straw is stored in mud-covered piles; this storage system can also be used for urea treatment of straw, which although well proven in the country, has been slow to take off with the smaller farmers.

Of lucerne and berseem hay, lucerne over the years has become important winter/summer fodder and is increasing as green feed, especially for equines, in Western Punjab. In the Northern Areas, particularly Gilgit, Skardu, Swat, Hunza and upland Balochistan, haymaking from lucerne is traditional. Berseem hay is prepared in irrigated areas of Punjab. This hay is fed in summer and winter fodder scarcity periods. The freshly cut material is sun dried. There are wide variations in the process. In the central irrigated tracts of Punjab, farmers, after harvesting the fodder, transport it to the farmstead, where it is thinly placed on the roof top or a protected area to avoid trampling and stray livestock. The favoured time is March/April for berseem, when the crop is at its peak of growth, flowering starts and the stem becomes more lignified. Drying takes 3-5 days, but there is a tendency to dry for longer time. Leaf shattering is extremely common.

Lucerne hay is made in large quantities in the Northern Areas and upland Balochistan. The crop is harvested any time between July and October. A village survey conducted in 20 hutments in Saifullah and Loralai (Balochistan) revealed that farmers with irrigated land invariably prepared lucerne and barley hay. The amount prepared was from 1 to 1.5 t per household, and done in small batches. The partially dried hay was made into bundles weighing 3 to 5 kg and, after complete drying, stacked indoors. The quality was excellent, with very little leaf loss. The recovery rate (yield of hay) was also higher (25-30%). In the Northern Areas, the hay is made into small bundles and mostly stacked on roof tops and covered with straw, polythene sheet or any other waterproof material. The hay is used between December and February when most of the natural vegetation is dry or unproductive, as a supplement to straw and other crop residues for cattle. For small ruminants, hay is fed in the evening, 0.5 to 1 kg per sheep or goat, but the quantity is highly dependent on grazing patterns.

In a study of small farms (1.2-2 ha holdings) in Gujranwala division, where an FAO project promoted haymaking of surplus fodder, the average herd composition was 3 buffaloes, 1 cow, 2 small ruminants, and 2 donkeys or bullocks. The feeding of dairy animals (those lactating) was given priority due to the commercial value of milk. Both in winter and summer, green fodder was fed (winter berseem or mixture of berseem, sarson or oats) at 30-40 kg per buffalo and 5- 10 kg wheat straw. During fodder shortages, the quantity of straw was almost doubled, with 3-4 kg concentrate (cotton seed cake, wheat bran, rice polishings). In summer, the major requirements were met through green feed. (maize, sorghum, sadabahar, millets, mott or Napier grass (*Pennisetum purpureum*)). The quantity offered per animal was 40-50 kg without any straw. Berseem hay, where available, was fed during the early summer fodder shortage. On 10 farms, with 2-3 lactating buffaloes each, the animals were offered 15-20 kg berseem hay, 5 kg wheat straw mixed with concentrate twice a day (e.g., 2-3 kg cotton-seed cake). Almost total maintenance and production requirements were met (milk yield averaged 8-10 litres). The study was carried out over a period of 45 days (1 May to 15 June, 1995).

Table 26. Approximate analyses of some dry feeds in Punjab (as percentage of DM)

	CP	EE	CF	NFE	Ash
Berseem hay	15.1	1.8	30.3	40.7	12.00
Lucerne hay	20.5	1.6	29.6	36.0	12.5
Millet stover	3.25	1.2	40.5	48.6	6.8

Notes: DM = dry matter. CP = crude protein. EE = ether extract. CF = crude fibre. NFE = nitrogen-free extract

CASE STUDY 10. HAY AND CROP RESIDUES IN PAKISTAN[1] - 2. HAY IN THE NORTHERN AREAS (A SETTLED COMMUNITY WITH SOME TRANSHUMANT STOCK)

These are arid to semi-arid zones in the rain-shadow of the Himalaya, and well north (Gilgit is 35°50'N) with a marked cool season; all agriculture is irrigated. Habitations, orchards and fields are in valley bottoms and lower terraces (altitude range 1 200 - 2 500 m); farm size is tiny. The area has always imported cereals, and the main cropping emphasis is on fruit and nuts as cash crops, and fodder for domestic use. There is little or no grazing on the steep slopes of the towering mountains around the villages, only some thin *Artemisia* where there is accumulated sand on the foot-slopes. Alpine pasture is available after snow-melt on the high tops (May to September) and village flocks and herds migrate there while grazing is available, and descend as the snows start. There is no source of natural hay.

The traditional fodders of these areas are: (i) lucerne, based on an old degenerate and very winter-dormant ecotype from Xinjiang, is all for haymaking; (ii) shaftal (*Trifolium resupinatum*) is usually from unimproved seed from around Peshawar; it produces little or nothing in winter but has a great spring flush and produces three summer cuts, and is liked because the young shoots are used as a table vegetable at a season when little else is available and because it makes good hay. It is mainly winter and spring green-feed, except at higher altitudes, where it is a summer crop; (iii) thinnings of very thickly sown maize; (iv) cutting green wheat in times of fodder scarcity; (v) planted trees and shrubs on field edges and marginal land which have adequate water (mulberry, willow and *Elaeagnus*), as their bark and leaves provide supplementary fodder in winter. Fallen tree leaves are saved as fodder (apricot and mulberry mainly), and all straws are very carefully stored.

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[1] Drawn from Dost, 1996.

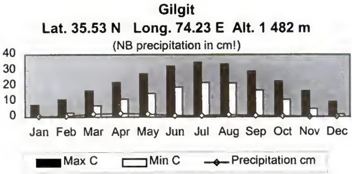

Figure 58. Temperatures and precipitation in Gilgit, Pakistan

Great improvements have been brought about in the past five years: preliminary screening showed that several fodder varieties which were already in use in other parts of Pakistan were well suited to local conditions. Their adaptation to both local conditions and farm needs was further tested through on-farm experimentation, which was followed by demonstration. The main improvements have been:

- Replacing the local lucerne by a non-winter-dormant cultivar. This has allowed several more cuts in most of the area, with yield increases of the order of 200% - 300% attained with good husbandry.
- Introducing multi-cut oats to replace wheat as green fodder. They resist temperatures down to -16°C at the higher altitudes, and down at Gilgit and Chilas produce feed at a season when no other is available.
- Using berseem instead of shaftal. This gives one or two cuts in autumn and winter, as well as a big spring flush, and greatly outyielded local shaftal. However, the comparison is not entirely fair, since good berseem varieties were compared with unselected local shaftal.
- Introducing maize varieties with good "stay-green" characteristics so that stover quality is improved as well as grain yield.
- Introducing multi-cut sorghums as specialized fodders for the summer, along with more rational cultivation of maize as grain.

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Uncontrolled grazing problem

When the herds and flocks come down from the mountains in autumn, traditionally all stubbles and fields are open to common grazing. This is very destructive for any fodders or other crops on the ground at that time. Stopping the destructive stubble grazing, which destroys fodders and early-sown crops, is an obvious way to increase overall feed availability. However, it requires community organization and decision-making, although some villages are already banning the practice and farmers are enclosing their fields. By the third year of the project's activities, 2 550 farmers were participating in activities and purchasing seed of the improved varieties (Dost, 1996). The varieties used are all commercially available from other parts of Pakistan and local general traders who supply traditional seed are being educated about the new varieties (including seed sources as well as crop performance and husbandry) and are encouraged to stock them.

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CASE STUDY 11. HAY AND CROP RESIDUES IN INDIA AND NEPAL[1]

THE SITUATION IN INDIA

Animal husbandry has been inseparable from Indian agriculture since time immemorial. Native knowledge and practices of stock-rearing were greatly enriched by the pastoral Aryans who first settled in the northwest of the country and spread throughout thereafter. Until the beginning of the twentieth century, feeding strategies were based on what was provided by nature; grazing formed the bulk of the feed and any shortfalls were made up by using tree fodder. Migratory and semi-migratory production systems minimized the shortages.

Rapidly increasing human population and urbanization disturbed this balance; the need for food crops led to a drastic reduction in grazing areas, with tree felling and consequent marginalization of the land holding. The demand for livestock products had a parallel increase and continues unabated today. The limited grassland production is very seasonal because of the rainfall pattern. To compensate for feed shortage, farmers made increasing use of crop residues and by-products, and these are now an integral part of livestock feeding systems throughout the country. The great demand for food limits fodder cultivation; rainy season surpluses from natural grassland are, however, made into hay in some areas.

Despite its many difficulties and fodder limitations, India has 15% of the world's livestock population (on 2% of the earth's land area). There has been a considerable rise in stock numbers in recent years and the national herd is now 450 000 000 head. The area under sown fodder has remained static at about 4.8% of the cultivated land. The limited forage production is a matter of national concern, and demand is rising sharply. Table 27 gives national estimates of requirements and supply.

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[1] Based on material supplied by Dr Bimal Misri.

Table 27. India's green and dry fodder availability and projected requirements (million tons)

	Availability	**Requirement**	**Shortfall** (%)
	Current		
Dry fodder (crop residues)	398.88	583.62	31.0
Green fodder	573.50	74.73	23.0
Concentrates	41.98	79.40	47.1
	Required by 2000		
Dry fodder	523.61	632.61	17.3
Green fodder	573.50	830.12	31.0
Concentrates	46.18	88.05	47.6

Source: Draft Report of the Policy Advisory Group on Integrated Grazing Policy, Ministry of Environment and Forest, Govt of India, 1993.

Through extensive efforts in research and development, the situation is improving progressively, albeit slowly. Since the early 1960s, fodder production has increased by seven to eight times, mainly through the introduction of high-yielding varieties and better technology to increase output from sown fodders per unit of land area. Degraded grassland has been improved through sylvi-pastoral systems allied to soil and water conservation, bringing biomass production on wasteland up to 8 t/ha. The contribution of agriculture to GDP (1991-1992) was 28.4%; domestic product from livestock as a percentage of all agricultural output increased from 8.6% in 1980-1981, to 21.3% in 1990-1991 (Singh *et al.,* 1995). Little cultivated fodder is conserved, as it is so scarce that it is all used green to supplement coarse roughages. Only during the rainy seasons, August-September and February-March, is hay made from the grazing areas in some parts of India. In order to feed stock during the lean seasons (October-December and May-June), crop residues are conserved in large quantities. These are low quality and coarse feeds, but are still very valuable in low-input systems of poor farmers.

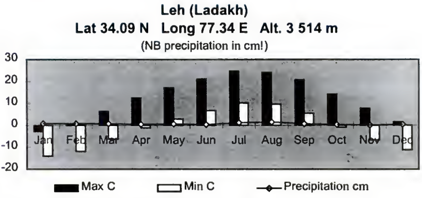

Figure 59. Temperatures and precipitation in Leh, India

LIVESTOCK-FORAGE PRODUCTION SYSTEMS

The great diversity of India's climate, topography, water resources, flora, fauna and ethnicity markedly influences land use and production systems. Livestock production, however, is common to all production systems. In some places, notably the arid and semi-arid zones of Rajasthan, Gujarat, etc., and the cold deserts of Ladakh, Lahaul and Spiti, livestock are the mainstay of the production system; food crop residues and trees are also major feed sources. The main systems may be classified as follows:

Peri-urban livestock production The peripheries of well-organized habitations, both small towns and large cities, are the source of daily milk supplies to the urban populace. The farmers in peri-urban areas rear a few (4 - 30) healthy, productive milch animals and grow vegetables for the remunerative city market. They grow fodder on a year-round basis as part of their rotation (maize, bulrush millet, sorghum and cowpea in summer; berseem in winter) - none is conserved. Wheat straw, maize stover and other crop by-products are stored and purchased from rural areas. With this system the use of concentrates is essential.

The urban system Only milch animals (cows and buffaloes) are reared in the urban areas (both large and small cities). The animals are kept in congested sheds and fed on seasonal fodders and crop residues bought from rural areas. In some places there are shops selling green fodder. In order to maintain high yields, the stock are fed concentrates and receive good care - they are the healthiest of any system.

The rural system About 80% of India's population live in the rural areas and are in some way involved in livestock production. All farmers - large-, medium- and small-scale or landless - rear livestock, which are both a source of income and an insurance of livelihood. The rural population lives in villages; each village has its grazing areas, which may be wastelands or well-identified grasslands. These grazings are neglected, mismanaged and very low-yielding. High yields are only available during the monsoon, and average dry-matter yields vary between 0.5 and 4.2 t/yr (Singh and Misri, 1993). Fodder cultivation has not really caught on, except in the states of Punjab, Haryana, Gujarat and western Uttar Pradesh. The commonest forage crop rotations, their yields and economics are given in Table 28.

Migratory grazing These systems have traditionally been practised in the Himalayas, but have spread to the deserts of Rajasthan and Gujarat and to some other parts of tropical India. Thirty migratory communities are described by Randhawa (1959). Migratory herds move from place to place following fodder availability. There are two categories: the semi-migratory and the transhumant systems.

Semi-migratory system This is practised by farmer-pastoralists in the Himalayas, who often have their permanent residences and crop-land in the foothills, as well as other, subsidiary, occupations. In summer, they take their stock to the sub-alpine and alpine pastures, where they stay from March to October. Right of usage of pastures is traditionally distributed between families, although the property rights remain vested in the state. Some farmers hire graziers to take the stock to pasture, and they are paid in both cash and kind.

Transhumant systems These are elaborate year-round systems of migration; the graziers do not have a fixed residence, although lately some have started having permanent households so that elders and young (for education) can stay behind. In tropical areas, migration starts when fodder becomes scarce locally. Migration may take place from Rajasthan to Uttar Pradesh during summer, with the herds returning at the onset of the monsoon (July). In the hills, particularly the Himalayan region, the upward journey from the plains begins in January-February and the flocks of sheep and goats reach the sub-alpine pastures in March; they graze in the sub-alpine and alpine zones till September-October, then travel back to the plains. On the plains, forage is always in short supply, and is supplemented by forest grazing, but the graziers always have to supplement grazing by purchasing crop residues and grazing time on fallows.

Table 28. Common forage crop rotations and the economics of their cultivation

Forage crop rotation	**Fodder yield** (t/ha DM)	**Production cost** (Rs)	**Net return** (Rs)
Berseem + mustard; Napier grass + cowpea	44.3	3 811	2.4
Berseem; mustard; cowpea + M.P. chari,	30.15	3 188	1.54
Berseem + mustard; maize + cowpea; M.P. chari + cowpea	33.25	3 209	2.17
Oat; bajra + cowpea; maize + cowpea	32.05	2 953	1.37
Oat; M.P. chari; turnip	37.4	3 645	1.47

Notes: *barja* is bulrush millet. *M.P. chari* is sorghum.
Source: Singh, P., 1988.

In Changtang (4 000 m altitude) the pastures are classified according to seasons. When grazing a pasture, care is taken to leave enough standing herbage, since the grass dries off and assures the necessary feed for the return migration. A herder, after grazing his stock in the winter pastures, starts the upward migration by grazing standing hay in the autumn and summer pastures - this allows sufficient time for the spring pastures to attain high growth and assures their sustainable vigour (Misri, 1993).

CONSERVED FODDER IN INDIAN LIVESTOCK PRODUCTION

Fodder conservation is as essential to livestock rearing as is fodder production; apart from seasonal scarcities, the pasture on offer is often so scarce that crop residues are fed throughout the whole year. A general pattern of mixed feeding in the mid-hills of the Himalayan region is given in Table 29.

Silage is rarely made, except for a few large dairy enterprises. Dry crop residues and hay from natural grassland are the conserved feed.

Table 29. Feed offered per day and per livestock unit in the mid-hills

Type of animal	Average live weight (kg)	Dry fodder (kg)	Green fodder (kg)	Concentrates (kg)
Cows in milk	198	6.3	5.3	0.25
Buffaloes in milk	413	8.3	2.25	0.1
Dry cows and heifers	244	4.4	3.76	-
Dry buffaloes and heifers	445	8.1	3.96	0.1
Bulls and bullocks	300	3.4	0.92	0.01

Source: Gill *et al.*, 1967.

Crop residues

The straws and stovers of rice, wheat, finger millet, maize, sorghum, bulrush millet and sugar cane tops are the major lean season feeds used by farmers, alone or supplemented according to availability and the financial status of the farmer. The average chemical composition of the major residues is presented in Table 30

Table 30. Chemical composition of some common Indian crop residues

	Percentage composition			
Crop residue	Organic matter	Crude protein	Crude fibre	Ash
Rice straw	82.0	4.0	37.0	18.0
Wheat straw	-	3.5	-	7.5
Finger millet straw	90.6	3.7	36.5	7.2
Sorghum stover	90.8	4.2	33.3	7.3
Maize stover	89.0	4.6	32.0	7.1
Sugar cane tops	92.55	5.0	32.0	8.5

Source: Available published literature.

In the Himalayan hills, even when grazing poor pastures, the animals often receive straw; Table 31 presents such a feeding regime.

Table 31. Supplementation of grazing animals in the mid-hills of the Himalaya

Type of animal	Hours/day grazing	Range of DM stall fed per 100 kg of body weight (kg)
Milch cows	7.7	1.08 - 2.44
Milch buffaloes	8.0	0.20 - 1.10
Dry cows and heifers	6.7	0.95 - 1.75
Dry buffaloes and heifers	8.0	0.74 - 1.66
Bulls and bullocks	6.7	0.66 - 2.98

Source: Gill *et al.*, 1967.

Rice straw

Rice is India's major food crop, with 43 million ha grown. The grain to straw ratio varies between 1:1.3 and 1:3. Bran accounts for about 15% of the paddy husk. Rice is harvested manually and threshed by hand, occasionally by bullock treading. Hand-beaten straw is of better quality and easier to store. Storage is usually in circular or rectangular stacks in the open field.

Wheat straw

Wheat, at 24 million ha, is India's second crop. It is harvested when the grain is ripe and the straw golden and brittle. Reaping is done manually, but threshing is by power or tractor-driven threshers, which break the straw into pieces 3 - 4 cm long, which avoids later labour for chaffing. The chopped straw is heaped in the field until stored, either under cover or in mud-plastered waterproof heaps. At the time of use, the straw is removed through a hole in the base of the mud covering. Chopped wheat straw is mixed with concentrates and water before feeding to stock.

Finger-millet straw

This is a rainfed crop, grown on 2.6 million ha. Ripening of the seed-heads is not synchronized; farmers harvest the ripe heads periodically and leave the stalks until the whole field is harvested (a period of 40 - 60 days). When the grain harvest is complete, the stalks are harvested. Some farmers harvest the whole crop at about 80% and leave the cut stalks in the field to ensure drying of the immature grain.

Threshing is by treading, and the straw is stored in the open field, which affects its quality badly. Straw stored under protection is of better quality.

Sorghum and bulrush millet stovers

Sorghum (*jowar*) is an important food in central India, being grown on 17 to 18 million ha. Stover comprises 40 - 60% of the total biomass. Panicles are harvested by cutting the tops of the plants; the stover is harvested separately. The plants are cut by hand and tied in small bundles, then stooked in the field in a way that allows good air circulation. Later, the stover is stacked near the homestead; it is fed chopped, mixed with green feed and concentrates. Bulrush millet (*bajra*) is grown on 12 million ha, mostly as a rainfed crop, and provides large quantities of stover, which is highly appreciated as a feed by the farmers.

Maize stover

Maize is grown on 6 million ha, producing 18 - 20 t/ha of stover. The crop is well distributed throughout the country, and its stover is an important feed. It is often sown mixed with cowpea or soybean; this improves the quality of the stover. Cobs are hand-harvested and the stover thereafter dried in the field, like sorghum. Green fodder is always mixed with the chopped stover.

Sugar cane tops

Sugar cane is grown on 3.7 million ha; it is harvested manually and part of the apical internode is usually left with the top. After harvest, the tops - which form 15 - 20% (25 - 30% of the cane yield) of the biomass available - are dried, stacked and used during lean periods.

Hay

Haymaking is localized in India; in most areas the grasslands are under such pressure that no herbage is available for conservation. In some of the peninsular states, like Maharastra and Gujarat, haymaking from protected forests and grasslands is very common. The major reason for the popularity of haymaking there is the lucrative market in big cities like Mumbai. Most of the hay produced in these states is sold and transported over long distances to places like Mumbai, Kashmir and Ladakh. Haymaking is also widespread in the hilly regions of the Himalayas: Jammu and Kashmir, Himachal Pradesh and the hilly tracts of Uttar Pradesh.

There are privately-owned grasslands and wastelands, but protected forest areas are the best hayfields. In the context of natural forest management plans, the state agencies close huge areas to grazing to ensure forest regeneration. The right to harvest grass may be auctioned or the local population is allowed to harvest the herbage free of cost. Village community grazing lands are also used for haymaking, using a participatory approach. Most of the grass cut is conserved as hay. Orchards, field bunds, riversides and other protected sites are also hay sources.

Himachal Pradesh is the only state where grasslands are privately owned; these are known locally as *ghasnis* and vary from 1 to 10 ha. They are protected from grazing during the growing season and the peak of herbage is during the monsoon, when it is very difficult to dry hay because of the heavy rains. Haymaking is therefore delayed until October, but by then the grasses are overmature and the quality of the hay is poor.

In the semi-arid areas, some farmers own wasteland unsuitable for development as arable land; these areas are grazed until the onset of the monsoon, then they are fenced with thorny bushes. The monsoon growth is made into hay in August - September. There is an unusual system of haymaking in the tribal areas of Gujarat: after the rice harvest in September, the fields are left fallow and wild grasses like *Dichanthium annulatum, Arthraxon* spp. and *Setaria* spp. form a sward which is harvested as hay, but after seed shattering, to provide the seed-bank for the ensuing year. The hay is kept for summer use. In the cold, arid Himalayan region, 30 - 40% of the cultivable area is planted to lucerne; traditionally one cut was taken in August, but now two or three cuts are made. The hay is tied in small bundles which are stacked on the flat roofs of the houses. As there is very little precipitation, there is no fear of the hay being spoilt.

Haymaking techniques

The techniques are age-old: the herbage is cut by iron sickles (except for the Buddhist Ladakhis, who use a yak-horn sickle, believing that lucerne cut by an iron sickle will not re-grow; they begin haymaking on an auspicious day fixed by the local monk). The cut herbage is spread over the field and turned several times till it dries. In Kashmir, the hay is made into trusses and hung on trees or tripods to complete drying. Usually, however, the hay is tied into sheaves bound by grass rope. Made hay may be stacked; it is often stored in trees. In some hilly areas, the hay is stored in attics. In Gujarat, Maharastra and parts of Madhaya Pradesh, with large quantities for sale to distant markets, the hay is baled. The botanical composition of hay varies from place to place, with the common feature that there are hardly any legumes. Only in parts of Kashmir might the hay contain small quantities of *Lespedeza* spp. Hay from both the tropical and hilly areas is very poor in quality, mainly due to late harvest. During the rains (July - early September), when the herbage is at its best, the weather is unsuitable for harvest and drying. It is consequently made in October, by which time the grass is overmature and drying off.

The potential and nutritional status of the herbage from the mid-hills is presented in Table 32.

Table 32. Composition of hays at different stages in the mid-hills of Himachal Pradesh

Grass and harvest date	**Chemical composition** (as percentage of DM)					
	CP	**EE**	**CF**	**Ash**	**Ca**	**P**
Themeda anathera						
Aug.	7.80	2.22	34.32	9.34	0.39	0.08
Early Sept.	5.90	2.02	33.54	10.32	0.52	0.08
Late Sept.	7.14	2.48	34.88	7.52	0.46	0.06
Early Oct.	5.01	1.89	35.53	8.53	0.45	0.05
Chrysopogon gryllus						
Aug.	8.11	2.76	33.07	9.65	0.39	0.08
Early Sept.	9.45	1.64	31.86	9.68	0.38	0.09
Late Sept.	6.87	1.58	33.86	9.28	0.38	0.08
Early Oct.	5.96	1.26	35.73	8.58	0.30	0.06
Andropogon pumilis						
Aug.	8.40	3.20	32.84	7.67	0.41	0.07
Early Sept.	8.00	2.85	31.73	5.84	0.37	0.08
Late Sept.	6.84	2.35	31.13	7.28	0.36	0.06
Early Oct.	5.23	1.82	38.43	6.14	0.34	0.05
Bothriochloa intermedia						
Aug.	11.63	3.33	34.85	12.15	0.54	0.08
Early Sept.	10.56	2.94	32.11	6.83	0.49	0.08
Late Sept.	10.28	1.63	38.86	7.50	0.34	0.05
Early Oct.	6.01	1.16	38.56	5.18	0.31	0.04
Heteropogon contortus						
Aug.	8.72	2.34	35.72	8.48	0.31	0.04
Early Sept.	5.84	1.64	35.34	8.17	0.34	0.08
Late Sept.	4.96	1.38	36.75	7.19	0.31	0.06
Early Oct.	4.78	1.06	40.43	5.76	0.28	0.04
Vetiveria zizanioides						
Aug.	6.72	2.12	34.72	9.04	0.29	0.06
Early Sept.	7.47	1.39	36.42	7.47	0.31	0.06
Late Sept.	6.12	1.06	41.53	5.35	0.28	0.06
Early Oct.	6.08	1.33	42.23	5.34	0.28	0.05

Key to columns: CP = crude protein. EE = ether extract. CF = crude fibre.
Ca = calcium. P = phosphorus.

Source: Gill *et al.*, 1970.

Management has a marked effect on yield: community grazing lands in the Himalayas produce about 7 t/ha of green matter, while privately-owned hay fields produce average fresh weight above 10 t/ha (Kotru, 1997).

There is a huge market for hay, straw and stover. Throughout India, it is common to find sales points for green and conserved fodder, but the marketing is not organized. Shops retail fodder in urban areas; some farmers bring fodder to town and sell it door-to-door for domestic livestock. The selling rates for hay depend largely on the transportation: hay originating from western India and sold to the Army in Ladakh may cost up to Rs 250 (about US$ 7) per kilogram. Farm-to-farm sales are usually by barter.

Table 33. Contribution of different plants to hay at Almora (1 500 m elevation)

Plant	Percentage contribution to hay
Heteropogon contortus	42.40
Chrysopogon fulvus	11.35
Mnesithea laevis	3.28
Arundinella nepalensis	4.05
Other grasses	17.39
Herbs	19.16
Shrubs	2.37

Source: Koranne and Singh, 1980.

Possibilities for improvement

The greatest limiting factor in hay production is the late harvest, which leads to low quality. Therefore, the possibility of communally managed mowing machinery and dryers should be investigated. Storage methods for hay and crop residues should be improved. Mechanical baling for transport of marketed hay requires improvement. Further work and extension on the urea treatment of crop residues is required.

HAY IN NEPAL

The situation in Nepal is similar to that in India, but since land holdings are even smaller and the terrain is mostly very broken, the feed situation is even more problematical. Livestock is an important component of Nepali farming systems and is the most important cash source for rural families. There are three distinct topographical regions: the *terai* is the plains and lowest foothills, tropical in climate; the hills (middle mountains which are highly populated and cultivated); and the mountains, which go to the snow-line and are largely pastoral. The hills, where the population pressure is greatest, is the toughest in terms of agricultural and animal production; land holdings are very small, averaging 0.71 ha, and terraces are made even on 50 to 60° slopes. Maize is the most important crop, followed by rice and wheat.

Integration of livestock into production systems is pronounced, the largest number of livestock being in the hills (mainly cattle, goats and buffalo). In the mountains, yaks and yak crosses (*chauries*) are very important, and transhumant systems are followed. Everywhere, crop residues are very carefully stored, often in houses or in trees, but the handling of wheat straw is less developed than in India and Pakistan, as it is a relatively recent crop in much of low- and medium-altitude Nepal. The main feed deficit is during November to February, when pastures are either snow-covered or growth is dormant. Tree fodder is widely used in periods of feed scarcity and many forests, especially of oak, are severely lopped. Hay is made in summer in the mountains and after the monsoon in the hills and terai, but the quantities available are always insufficient. Hay and straw are rationed during the season of scarcity to maintain the livestock, but often in insufficient quantity and quality for growth, so many of the hill cattle are stunted. Since the total quantity of conserved feed is insufficient, straw treatment with urea, which would improve feeding value, but also increase intake, is pointless.

In the high mountain areas, haymaking practices vary from one ethnic group to another; some have long traditions of making hay from natural pasture, others do not do so although the seasons are harsh throughout these lands fringing the snows. Transhumance is practised (sometimes routes overlap and what is summer pasture for cattle herds from low down become winter grazing for yaks and chauries) but that does not suffice to provide cold-season feed. Yellow-flowered lucerne (*Medicago falcata*) occurs naturally around irrigated lands and in protected sites in the high valleys, and is valued as a fodder and hay plant.

Table 34. Information on three livestock systems in Nepal (Average per household)

	Naubisse	**Dhuskun**	**Yelung**
	970 - 1 100 m	1 150 - 2 250 m	2 200 - 2 400 m
Holding size (ha)	3.68	2.45	6.95
	Herd composition (head)		
Cattle (adult male)	0.53	0.57	1.07
Cattle	0.53	1.10	0.60
Chauries(1)	-	-	4.04
Calves	1.20	0.53	0.76
Buffalo (adult male)	-	0.07	0.03
Buffalo (adult female)	1.10	0.56	1.43
Calves	0.57	0.23	0.87
Goats	2.44	2.73	2.96
Sheep	-	-	0.07
Poultry	1.77	3.70	2.20
	Animal feed consumption		
Green feed (kg TDN(2))	676	792	1405
Dry roughage (kg TDN)	1379	913	253
Concentrates (kg TDN)	244	54	41
Grazing (hours)	298	686	2018
Bedding material (kg)	11182	757	797
	Milk yield (litres/lactation)		
Cows	428	225	254
Chauries	-	-	307
Buffaloes	1065	524	595

Notes: (1) *chauries* are cow x yak hybrids. (2) TDN = total digestible nitrogen.
Source: Yadav, 1992.

Table 35. Labour need, crop and by-products of three crop production systems in Nepal

Crop and sites	Labour (work-days)	Bullock power (pair-days)	Yield of main product (t/ha)	Yield of by-product (t/ha)
NAUBISSE				
Early paddy	223	38	2.97	3.24
Normal paddy	194	41	2.70	3.21
Wheat	157	39	1.68	2.72
Maize	179	43	1.77	3.38
Finger millet	158	15	1.03	1.72
Sugarcane	197	33	15.40	7.5
Mustard	112	39	0.66	0.82
DHUSKUN				
Normal paddy	167	43	1.72	1.97
Wheat	143	37	1.23	2.27
Maize	172	46	1.49	2.55
Finger millet	164	-	0.95	1.71
Mustard	89	32	0.51	0.74
YELUNG				
Wheat	148	41	1.15	2.10
Maize	167	44	1.53	2.83
Millet	149	-	0.88	1.69
Barley	109	37	0.66	1.19
Buckwheat	107	36	0.90	1.39

Source: Yadav, 1992.

CASE STUDY 12. ALFALFA HAY PRODUCTION BY SMALL-SCALE FARMERS IN THE CHACO - A SEMI-ARID REGION IN SANTIAGO DEL ESTERO PROVINCE, NW ARGENTINA[1]

The province of Santiago del Estero, in the heart of the semi-arid Chaco region in northwest Argentina, has a variable climate, both within and among years, because of erratic rainfall. Precipitation decreases from east to west; average annual rainfall is 716 mm (1008 mm high and 455 mm low) concentrated in the summer months (October to April). Summers are warm and humid; winters are cold and dry. The evaporation/precipitation balance is negative throughout the year (see Figure 61). Soils are prone to degradation (by wind and rain), but have no mineral deficiencies, with phosphorus and calcium in adequate concentrations.

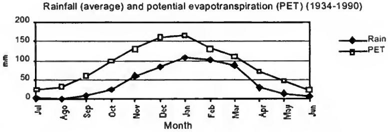

Figure 60. Rain and potential evapotranspiration (PET) (average for 1934-1990) for Nueva Esperanza, Pellegrini Department, Santiago del Estero, Argentina.

The natural forest comprises xerophytic species, among them trees, including (quebracho blanco (*Aspidosperma* sp.); quebracho colorado (*Schinopsis* sp.), *Prosopis nigra*, *P. alba* and *Ziziphus mistol*); shrubs (*Acacia aroma*, *Schinus molle*, *Cercidium australe*, *Celtis spinosa*, *Capparis* sp., etc.); grasses such as *Setaria* sp., *Trichloris* sp., *Digitaria* sp., and *Pappophorum* sp.; and dicotyledonous species such as *Justicia squarrosa*, *Wissadulia densiflora*, etc. The native vegetation is an important fodder source for cattle and goats, which feed on leaves, branches and fruits. Forage quantity and quality are highest in the summer.

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[1] This case study was prepared by Hector Eduardo Perez, INTA, Santiago del Estero.

Table 36. Number of producers by type and production zone

Type	Zone				Total
	Dulce River	South Salado River	Horcones River	North Salado River	
Small-scale farms (<5 ha)	850	600	400	700	2 550
Medium farms (6 to 50 ha)	20	100			120
Big farms (>50 ha)	30				30
Total	900	700	400	700	2 700

The main productive activities in Santiago el Estero are cattle rearing, forest development (for charcoal, poles and railway sleepers), and agricultural crops such as cotton, maize, soybean, beans and alfalfa, grown with or without irrigation. Alfalfa is produced in some parts of the province, by various producers using diverse technologies. The main areas are along the rivers Dulce and Salado. The common factor in all the areas is the small-scale farm producers.

The study area

The area lies between 26º 15′ S and 64º 10′ W, in the Pellegrini Department of Santiago del Estero Province. The area is far from major towns, such as Santiago del Estero (240 km) and Tucumán (140 km), and from the province of Salta (100 km). Rural roads link the area with these cities. The most important town is Nueva Esperanza, which has services such as schools, sewerage system, running water, electricity and shops. The rest of the area has no running water, only some wells with water of poor quality for human or animal consumption. These wells supply producers with water, especially in the winter. Most farms have water reservoirs where water from rain or wells is collected.

Description of small-scale farm systems

Types of Producers

There are over 400 small-scale farm producers in the area, of which approximately 200, organized in ten groups, are members of this project, aimed at strengthening the organization and productivity of producers. The usual country family is headed by a father, who is the main and often only provider.

Most fathers (66%) are over forty years old (Table 37) because most men emigrate when they are very young, and come back to stay at home when they reach this age. To supplement earnings for basic needs, farmers with small holdings must go to other places, such as Salta or Tucumán, to work as bean or sugar cane harvesters, or on big farms. In some months, it is normal see no men on the farms because they are working away from home. The women and children have then to care for domestic animals and crops, and cultivate small vegetable plots for family consumption. The average family has five children, but 50% of the families have six. These children are the family labour force until they reach the age of fifteen, when they usually leave.

Table 37. Producers age and number of children for the families in the case study

Age in years	%	No. of children	%
20 - 40	34	0 - 3	25
41 - 60	66	4 - 6	75

Sample size: 78 families.

The rural home, known as *rancho*, is built with local material, such as wood from *Prosopis*, *Schinopsis*, etc., with adobe roofs and walls. Many producers, however, have begun to build modern houses, using concrete blocks with zinc or concrete roofs. The kitchen and toilet are usually separate from the bedrooms.

All the producers own their farmland. Many land plots average 6 ha, but less than 2.5 ha is productive (Table 38). Only the cultivated part is fenced; the rest of the land is open and it becomes a communal area for animal grazing. The natural pasture, because of the absence of stocking rate management, is in a poor condition, with low forage production and a limited recovery time.

Table 38. Distribution of the total and cultivated areas by percentage of producers

Total farm area (ha)	%	**Area cultivated** (ha)	%
< 5	62	< 1	12
5 to 10	31	1 to 4	77
> 10	7	> 4	11

Sample size: 78 families.

INTA is trying to ameliorate this situation by fencing these areas with electric fences, establishing areas banned to animals, seeding subtropical pastures (mainly grasses) and managing stocking rates. Arable land is developed by forest clearing and subsequent preparation and cultivation with the farmers' own implements. However, the land preparation is not ideal because of ground levelling problems, which still prevail after several years of cultivation. Resolving this constraint would allow better use of irrigation water, and decrease watering time and cost. Farmers sow between 0.5 and 4 ha with alfalfa; the average is 1 ha. The rest of the arable land is planted to maize, squash, melon and watermelon production (Table 39).

Table 39. Distribution of cultivated area and by percentage of producers

Alfalfa	%	Maize%	
< 0.5 ha	37	< 0.5 ha	31
0.5 to 2 ha	49	0.5 to 2 ha	55
2 to 4 ha	14	2 to 4 ha	14

Sample size: 78 families.

Maize is the main cereal (see Figure 61) and production is based on regional varieties, with low technical inputs. Incomes are low, because yields do not exceed 1 t/ha. Production is for the producer's own consumption and his livestock; any surplus is sold or bartered. The stover is all used as forage. Maize is grown by all the farmers in the area, so improving its productivity can have a very significant impact. Technology must be oriented to improve grain yields through new cultivars and improved management, especially considering stubble management and incorporation of organic matter into the soil.

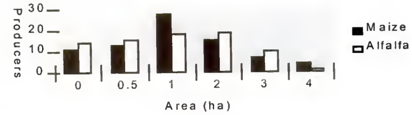

Figure 61. Distribution of maize and alfalfa area by number of producers

Most producers (78%) have horses for transport and draught, and also have pigs (79%). An increase in poultry, and, to a lesser extent, cattle (44%), goats (26%) and sheep (18%) has been observed. The basic diet of these animals is from three sources: alfalfa, crop residues (mostly maize) and natural pasture. Since horses need to be kept close for work and transport, they are fed with alfalfa (either fresh or dry), fodder maize stubble, and, sometimes, natural forages. Agricultural plots are the only fenced land producers have, the rest being open. Pigs are fed with fresh alfalfa and maize, and occasionally forage in natural woods and stubble. They are kept in pens mainly during birth and rearing. Cattle, goats and sheep (for meat) feed mostly on natural pastures.

Cultivation is mostly with animals (horses and mules). Simple ploughs and tooth harrows are used, and other hand-tools to cut and rake. Some producers in the region have farm machinery (such as tractors and harrows), which can be rented by other producers, who pay per hectare. The provincial government offers an alternative by placing "mechanized stations" in the zone, that provide services to producers, who only pay for fuel, with maintenance and personnel paid by the government.

The irrigation system is old, based on water some producers derive by channels from the Horcones River; other farmers pay fees for channel use. Irrigation is possible while the river carries water (usually during the rainy season, when irrigation needs are lower). During the summer, the water reaching the area is insufficient, so water must be taken from further north (El Mojón o La Fragua). This increases costs, which are estimated to be $ 2-3 per hour, and between 6 and 16 hours are needed to irrigate one hectare, depending on the volume. On account of the cost, producers farthest away are deprived of irrigation due to the distance from the water source to the plots (approximately 30 km). Water quality is good (with sediments) during the rainy season, but it decreases in the dry months, as the salt concentration increases, though levels are still tolerable for crops.

Irrigation availability is an important constraint to production, because water availability is not permanent and its management is still in the hands of big producers. To solve this situation, an integrated effort by the provincial government and producers is required to build a channel with a greater capacity. It will allow delivery of larger volumes of water at the times of high crop demand. The system should be operated by groups of producers.

Alfalfa

Alfalfa is the main crop in terms of its contribution to family income, providing food for the most part for domestic animals. In rotation with other crops (maize, cucurbits), it improves nitrogen availability in the soil.

Soil preparation for seeding is as follows: the soil is worked once with a mechanical harrow. This service is paid for, costs ranging between $ 35 and $ 40/ha. Frequently, during periods of high demand, there is a shortage of equipment for this service, making it difficult to prepare the soil for seeding. The work is not usually satisfactory, because it tills only the upper 10 cm, leaving clots and weeds (for example, *Cynodon dactylon, Sorghum halepense*), so the producers have to do final seed-bed preparation using tooth harrows.

Between 25 and 40 kg/ha of seed is usual. The excessive quantity of seed is because of low botanical and physical quality. The seed is produced by farmers themselves, from the hay fields. Sowing is manual, by spreading the seed and then covering using a branch dragged by horses.

Eighty percent of the alfalfa area is seeded with the Saladina ecotype (Creole). It is not resistant to aphids and has a period of dormancy. Productivity is good, but the quality is low because of the large stem-to-leaf ratio.

After sowing, plots are irrigated, to allow seeds to germinate and establish quickly. At least 2 hours of irrigation are necessary, because of bad soil levelling, bad seeding and the low water volume.

Harvest is manual, using machetes or scythes. Plants are usually cut very close to the ground, to control weeds and renew the crown. This type of harvest does not take into account re-growth from the base. Four to five days are required to harvest each hectare, and an additional day to manually turn the alfalfa to ensure drying: a tedious and exhausting job. Some producers use a hand rake with 30-cm-long teeth to drag the cut fodder into windrows. The dry herbage is then loaded into a *zorra* (a long narrow cart) and taken to the backyard (if more drying is needed) or a shed. Eight cuts are made annually.

The main pest of this cultivar is *Aphasia*. Perfektion™, applied with bags, is used to control it. Though recommended quantities are applied, there are mistakes in bag calibration, and distribution when walking through the lot. The beneficial fauna is not recognized by farmers and it is not respected when applying insecticides. Little red spider can be a pest in dry conditions and with high temperatures. It is also controlled with Perfektion.

Bales are made by an artisanal procedure. Bottomless boxes, built from the algaroba tree (*Prosopis juliflora*), are laid on the ground and crossed with plastic fibre to tie the bales. The hay is then added and packed until the required weight is reached, and the bale tied. A pack usually has 7 pieces and weighs between 8 and 14 kg.). Alfalfa bale production is variable during the year. In spring and summer months, it is about 150 bales per hectare cut, while in the rest of the year it drops to 80 per hectare cut. Annual average production is estimated at about 920 bales/ha. Because of the variability in bale weight it is hard to estimate the dry matter produced per hectare.

The hay quality is very good (in colour and dryness), because of the way the producers work the alfalfa. After cutting, the forage does not remain more than 24-36 hours in the open before it is moved to the store, where it continues to dry until the right humidity for baling is reached. The forage retains a dark green colour and a high leaf percentage. The green colour of the hay, the leaf content, the drying and the absence of weeds are the qualitative parameters of quality used in commercialization.

The bales are sold to buyers who come from Salta and Tucuman, and prices range between US$ 0.80 and 3.00. The lowest prices are because of excessive supply in summer months. At that time, production is high and there is low demand, aggravated by the producers need of money and the scarcity of storage capability, which forces them to dispose of the product.

Technical assistance

Under these circumstances, technical assistance has the following objectives:

- To improve alfalfa production through adequate field management practices, including land levelling, seeding time, determination of cutting time, and harvesting systems.
- To introduce alfalfa varieties that are more productive and resistant to insect pests and diseases. This includes identifying diseases, pests and beneficial insects, control methods and specific control products, and establishing dosages and application procedures.
- To consolidate the organization of the groups, and to motivate and strengthen the groups for developing integrated activities, including problems and solutions analysis, buying and selling products, and making joint demands for the solution of regional problems at local and regional government level.

Activities towards attaining the objectives include group meetings and personal visits, where socio-organizational and technical production topics are considered. In addition, there is also training provided by experts in the relevant fields.

To assist consolidation of group organisations, other group institutions are used: meetings of delegates and a Group Federation. Together, they consider common aspects of the regional problems and try to suggest solutions. Training related to socio-organizational problems is the responsibility of technicians from the Social Livestock Programme (SAP- a national programme of the Secretariat for Agriculture, Fisheries and Food). It developed the idea of persuading the Group Federation to address irrigation problems. Another topic that has been proposed to the groups is the joint marketing of alfalfa bales, to reduce price fluctuations. When prices are low, bales are stored in a communal storage facility and producers receive the market price. Later, when prices increase, bales are sold and producers receive the difference. To begin this system, SAP lends money to producers for both the construction of the store and to establish a capital fund to pay the low market price for the bales. The producers commitments to the group consist of paying back the loans, in giving part or all of his bales to this system, and to contributing a percentage of sales to maintain the capital fund.

To support training in technical production aspects, some demonstrations were established in three small producers lots. The cultivars used were Cuf 101, INTA Salter and others. The aim of the trials is for producers to see and compare the behaviour of these varieties with the Creole. They will also serve to demonstrate some technical management practices recommended for the improvement of alfalfa crops, namely:

- levelling of the plots by using practical levels (tubes) and the use of simple implements and animal power;
- early preparation (a long fallow period before planting) of the ground to control weeds and finish seedbeds;
- sowing at the correct time in autumn (mid-March to mid-May). The best time is April, because temperature and humidity are optimum to ensure fast germination, emergence and establishment. There is also less competition from weeds;
- sowing in 12 to 15 cm rows, by using an animal-drawn seed-drill;
- programmed cuts according to basal re-growth or 10% bloom;
- observation of the decrease in the plant stands and comparison through the years;
- recognition of beneficial insects (parasites and predators of pests) such as coccinelids, microhymenopters, carabids, hymenoptera and diptera; and
- correct use of specific pesticides.

In those experimental plots, quality evaluation and comparison between the Creole and other cultivars is carried out all year. These comparisons include leaf:stem ratios and several chemical analysis, including fibre (ADF, NDF), crude protein (% CP) and *in vitro* digestibility. Technicians from INTA EEA Santiago del Estero are in charge of training producers and carrying out the experimental trials.

Economics of alfalfa production

The economics are based on costs of establishment, production costs and gross returns from crops for hay. To calculate the costs, the farming system characteristics shown in Table 40 were used. To analyse the costs, all of the producers' expenses were considered, as well as costs of machine services or hiring workers. The costs were divided into establishment and production costs. The former includes expenses for soil preparation (cost of services), irrigation, and seed. These are amortised over four years, considered to be the useful life of an alfalfa crop. In the production costs, all the expenses involved in bale handling, crop protection and irrigation were considered. The highest costs are hired help for cutting, raking and baling. Hiring is mainly in the months the producers are away from home, working in other places. The analysis is shown as Table 41.

Table 40. Farm system parameters for alfalfa production

Annual yield	920 bales/ha
Cuts per year	8
Spring-summer yield	150 bales/ha
Autumn-winter yield	80 bales/ha
Average bale weight	14 kg
Average bale sale price	$ 1.53
Crop life	4 years

Table 41. Costs and returns in alfalfa production

		A - Total cost ($/ha)	B - Work-days per farmer
1	Establishment costs (discing, seed, irrigation and irrigation work)	161	8
	Establishment costs on a per-year basis (A or B amortised over 4 years)	40.25	2
2	Production costs (irrigation, pesticide, mowing, raking, carriage to shed, baling, baling twine, feed for work horse)	600.90	53
3	Total direct costs (1 + 2)	641.15	55
4	Total gross return (yield price)	1 407.6	
5	Gross margin (4 - 3) $/ha years	766.45	
6	Equivalent day work (5/3B) ($/dw)		13.94

The annual gross margins per hectare for the producers are acceptable, compared to other production alternatives in the region. The bale price is high compared with bales from other regions, which are heavier (20 kg). When we consider the gross margin related to the days the producer works in alfalfa crops, it is 40% higher than the daily wages he receives working away from the farm. The producers' main source of income comes from this system of bale selling, and it is supplemented by off-farm work, in other provinces. Sometimes the sale of animal products (such as young goats, domestic fowls, eggs, etc.) increases family incomes. Subsistence consumption prevails in most families.

Conclusions

With this project, INTA - SAP is endeavouring to increase the standard of living of producers. This goal will only be reached if there is a joint effort between producers and government institutions. This project became operational in 1995, and already important advances have been achieved in organizing producers (grouping; common problems analysis and solution; and commercialization) and in improving the alfalfa crop. There are still many aspects to cover, both organizational and technical, but the only way is to strengthen relationships between producers and technicians. In this process, nothing is imposed: it begins with a statement of the problems by the producers, a proposal for solving those problems by the technicians, and a search for financial support, as cash loans or subsidies. Producers have understood that only joint efforts will succeed: forming working groups, training themselves and leaving personal demands aside. At the same time, the technicians have learnt to understand the producers' timing and to respect their empirical knowledge, resulting from years of accumulated daily experience. It is clearly not an easy task, but the journey has been started and there is no turning back.

CASE STUDY 13.
DRY-SEASON FEEDING:
A CASE STUDY FROM NICARAGUA

Nicaragua, with an area of 130 700 km², lies between Costa Rica and Honduras. The capital, Managua, is at 12°06'N and 86°18'W. Three agro-climatic zones are distinguished: the Pacific, the Central and the Atlantic zones.

The Pacific zone, with an area of 28 000 km², has an annual rainfall between 600 and 1800 mm, distributed over 6 months (May till October); 90% of the area receives under 1000 mm per year. Soils are derived from volcanic material and are deep, sometimes with impermeable horizons. Soil texture is mainly sandy loam, except for some limited areas with clay soils. The topography is characterized by hilly terrain with gully formation. Average annual temperature varies between 25.5°C at 1 000 m and 28°C at sea level.

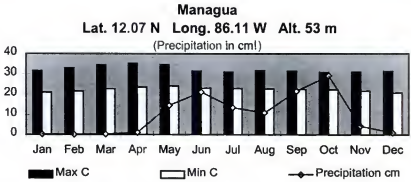

Figure 62. Temperature and rainfall patterns, Managua, Nicaragua

This study is from the Pacific zone. Livestock production is still in crisis due to the civil instability and political upheavals of the 1980s and early 1990s. During the "golden period," between 1975 and 1979, livestock and livestock products comprised 30% of GNP. In 1975, the cattle population was estimated at 2.5 million; now - in 1997 - it is estimated at between 1.5 and 2.5 million (the

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1. Based on material contributed by Ir. Pascall Eleegert.

agricultural census scheduled for 1997 should provide more exact data). In the Pacific zone, 29% of the animals are kept in 21.4% of the national territory. The animals are mainly general-purpose cattle. No specific breed description can be given, due to indiscriminate crossing of the indigenous breed (Criollo) with Pardo, Brahman and, to a lesser extent, Holsteins. Some typical production parameters are: first calving at 4 years; calving interval 18 -24 months; average milk production 2.5 litre/day (calf suckles one teat) for an average of 8 months; and average daily weight gain 250 - 300 gram. Sheep or goats are insignificant in the Pacific zone.

The farming system is predominantly mixed farming, cultivating maize (*Zea mays*) and beans (*Phaseolus vulgaris*) for home consumption, with any surplus sold on the local market. Other important crops are sorghum (*Sorghum bicolor*) for the poultry feed industry and sesame seed (*Sesamum indicum*) as an export product. In recent years, the big farmers have begun to grow soybean (*Glycine max*) for oil extraction, and groundnut (*Arachis hypogaea*) for export. A typical small-scale farmer has, roughly, less than 4 ha; a medium-scale farmer, between 5 and 40 ha; above 40 ha is considered to be large-scale farming.

Animal husbandry is an important component in the farming system of the small- and medium-scale farms of the Pacific zone. Among domestic animals, bullocks are the most important; they are used for transport in the rural areas, carrying firewood, and drawing water from wells more than 100 m deep. Furthermore, bullocks are the essential draught power for the small-scale farmer during cultivation, facilitating activities like land preparation, sowing, weeding, earthing up and carting the harvest. Dairy animals are kept by small-scale farms for milk and dairy products (cream, butter and a fresh cheese named *cuajada*) for home consumption. Medium sized farms, with over 20 ha of land and more than 10 animals, manage to earn a partial or sole income, in the case of a specialized dairy farm, by selling fresh milk, dairy products and every now and then a live animal.

The predominant feed is pasture and fodder trees. (Garcia Guillen, 1996) The animals are usually kept year-round on open pastures dominated by natural species, which include aceitillo (*Aristida jorrulensis*), zacate torcido (*Heteropogon contortus*), zacate rosado (*Rhynchelytrum roseum*), grama bahia (*Paspalum notatum*), pata de gallina (*Eleusine indica*), pasto ilusión (*Panicum trichoides*), zacate gallina (*Cynodon dactylon*), and pendejuelo o salea (*Digitaria sanguinalis*). Since the 1980s, improved pastures have been sown with gamba grass (*Andropogon gayanus*), star grass (*Cynodon nlemfuensis*) and Napier grass (*Pennisetum purpureum*) in the sandy loam soils, and with Angleton

(*Dichanthium aristatum*) on clay soils. To a very small extent, the more advanced farmers are using King grass (*Pennisetum purpureum* x *P. typhoides*) and sugar cane (*Saccharum officinarum*) as a cut fodder for dry-season feed. With regard to fodder trees, the jícaro (*Crescentia alata)* in the clay pastures is highly valued for its fruits, which are available in the dry season. The seedlings of the jícaro trees are for this reason tended and sometimes protected (animals are responsible for the distribution of the seed).

Planting of trees for fodder is nonexistent. The use of tree fodder is limited; farmers know and occasionally benefit from the leaves and fruit of trees like guanacaste blanco (*Albizia caribaea*), guanacaste negro (*Enterolobium cyclocarpum*), guácimo de ternero (*Guazuma ulmifolia*) and genízaro (*Samanea saman*). Two native trees which both have a high potential for high quality fodder (protein content of 18 - 28%), namely *Leucaena* sp. and madero negro (*Gliricidia sepium*), are very little used for animal feed.

Dry-season feeding is survival management. It is estimated that animals lose 50% of the weight gained during the rains. The main animal feeds during the dry season are the residues (straw, stubble and husk) from maize and sorghum. Depending on the rainfall and agronomic practices, between 2 and 3 t of stover is produced by sorghum and maize crops. Farmers with more animals than their own land can sustain have to rent additional agricultural land to graze their animals, paying from US$ 0.05 per animal per day, up to US$ 0.10 in periods of extreme fodder scarcity (when the rainy season starts, after the third week of May). Although very little straw is left after the harvest of the soybean and groundnut crops, these lands are also rented to graze animals. Soya residues are liked by the farmers because they raise production. Farmers are very keen on a daily offering of salt to their animals in order to encourage them to drink much water and a thus resist the dry and hot season.

Additional practices are feeding cane tops and the bagasse collected from the local traditional cane presses. Groundut hulls are collected from the processing factories, and given to cattle after sprinkling the hulls with molasses diluted with water. One high quality and locally available complement is the fruit of the jícaro tree. During the dry season the fruits are collected, left to mature, and then broken to feed the pulp and seeds to selected animals: dairy animals, animals in weak condition, and weaned calves.

There is also a traditional practice, which is the cultivation of *guate,* a fodder crop of maize or sorghum for dry-season feeding. On the lighter sandy loam soils, maize is commonly used, while on the clay soils, sorghum is better adapted. The crop is sown at the end of the rainy season (September or

October), to benefit from the last showers, or in some cases the crop just grows on the basis of the residual soil moisture. The soil is prepared using tractor, plough and harrow, and the seed broadcast or in furrows. High seed rates are used - from 60 to 120 kg/ha - for both sorghum and maize, to avoid thick stems in the fodder crop. The production of such a fodder crop is between 5 000 and 10 000 kg/ha of dry feed, assuming a dry matter percentage of 90% or higher, given the lengthy period of field drying. After 90 - 120 days (in December or January), the crop is pulled up, including the roots, and left in the field to dry for between one and two weeks. The material is then collected and made into bundles, using the same material to make a tie. Each bundle weighs 2 to 3 kg, and these are then brought to the farm and stacked, sometimes around a central post, in a shady place or open area. No plastic or other material is used to protect the fodder against the burning sun during the entire dry season. If possible, this fodder is kept until March or April, when they start feeding it either to those animals which the farmers judge to need it most (animals in poor condition and weaned calves) or to condition the bullocks. This fodder is mainly used as a complement, fed dry during the late afternoon in the pen after the animals have returned from the stubble fields.

Protein deficiency in the animal feed supply is very evident during the dry season, and even partly during the rainy season. Concentrates are not used, because they are commonly felt not to be profitable because of their relatively high price - US$ 22 per 100 kg, while milk fetches US$ 0.25 at the farm gate and US$ 0.35 to the consumer in town.

Straw treatment has been tried on a pilot scale by a few projects. Direct costs involved are around US$ 0.80 for N fertilizer, and US$ 2.00 for plastic per 100 kg of straw treated. Urea-molasses blocks were also tried on a pilot scale, costing US$ 13 for the ingredients alone.

CHAPTER XII

SMALL-SCALE FARM HAY IN THE FUTURE

Technology for haymaking on large, mechanized farms is developing rapidly. Small-scale farm haymaking, as has been so well illustrated in the case studies, relies on age-old, traditional methods, equipment and crops; how and where can improvements be made in the context of small-scale farms' socio-economic conditions? Direct transfer of methodology developed in other farming and economic contexts rarely works, so what improvements can be foreseen? The realization of the value of crop residues as roughage for livestock is widespread and increasing, and in areas where they used to be grazed, they are often harvested for domestic use or sale.

HAY

Expansion of haymaking from natural pasture in areas where it is traditional is probably limited by the availability of suitable herbage. Technical improvements, from clearing, drainage and sometimes irrigation, to resting and fertilizing, are possible if the problems of long-term cutting and grazing rights are resolved. It remains to be seen if the harvesting of coarse, tropical herbage will expand, since its quality is always low and climatic conditions usually preclude curing it before maturity. The possibility of improving harvesting of crop residues should be studied before encouraging the harvest of bush hay. There are, however, great areas of degraded grazing land, especially in monsoonal climates, which could be reclaimed as pasture if the people became involved and, in such climates, conservation of fodder for the very long dry season is essential.

Hay from sown forage is of much higher quality than that from natural pasture, especially legume hay, which is the mainstay in many traditional systems. Considerable improvements are possible in the growing of hay by using good seed of locally proven cultivars, careful cultivation, mineral fertilization and better irrigation where appropriate. The expansion of sown hay into tropical small-scale farm systems is problematical, at least in humid and sub-humid areas: there is no legume to replace lucerne and the clovers as a hay crop. Much hay is produced under irrigation in semi-arid and arid areas; there, availability of irrigated land is a limiting factor to expansion, and the main method of increasing hay appears to be through raising yield per unit area.

Suitable grasses abound, but making hay from them in any quality under such conditions, in anything except tiny quantities, would seem to require mechanization so that mowing and swath manipulation can be effected rapidly enough. Hay in the tropics, to date, is associated with large-scale commercial farming where livestock is important.

Usually the available cultivars are not a major constraint to improving production, although seed availability and quality may be (see below). In traditional haymaking areas, small-scale farms can often attain large increases per unit area by using good seed of cultivars already available through local research institutions. Where hay is already grown, therefore, more emphasis is needed on screening local landraces and defining problems before searching for "high-yielding" crops; hardiness and persistence under the often low-input systems which are common, are essential characteristics. It is, of course, desirable to keep up-to-date with advances in disease and pest resistance. The main small-scale farm hay crops are legumes; sown grasses are little used. Lucerne stands out as the main crop in a great many countries where small-scale farm haymaking is traditional; it is also, of course of paramount importance in large-scale farming. Sainfoin, *Onobrychis sativa,* is a traditional crop grown alongside lucerne in parts of western Asia and seems adapted to poorer soils and conditions, but its use has not spread. Does it merit wider testing and study? Another crop which is very important in its traditional area but has not become widespread is Persian clover (*T. resupinatum*).

Problem areas include those with very severe winters, some of which can only use their own landraces, so breeding and selection must be local; very high altitude zones; and the cool limits of the subtropics.

Limited supplies of seed and planting material of adapted varieties is a major constraint to the improvement of hay production in developing countries. Any programme to increase fodder supply will have to address this at the outset. Fodder and pasture species present greater problems in on-farm seed multiplication than do cereals and pulses. Cereals used as fodders are usually easy in terms of seed production, but producing good seed of specialized fodder (and pasture) grasses and legumes requires special skills and equipment, and is usually grown in specialized micro-ecologies. Where holding size is very small, farmers often prefer to buy in rather than use valuable land (and irrigation) on a seed crop. Production by specialist farmers should be encouraged, rather than each small-scale farmer growing his own. International trade concentrates on cultivars commonly in demand in developed countries, and these are not necessarily suited to other areas. Some of the major fodders of developing countries (e.g., berseem, *Trifolium alexandrinum)* and most of the pasture crops are little grown in developed countries. Although it has often been amply demonstrated that the use of clean seed of an adapted cultivar is the first prerequisite in improving fodder production, the multiplication and marketing of locally adapted fodders lags far behind that of food crops in most developing countries. Improvement of fodder seed supply, which would increase yield per unit area for small, land-scarce farms, is essential if animal production is to be raised. Absence of an official seed production structure is not a bar to fodder production where a vigorous farming community traditionally grows fodder: the Afghan lucerne and shaftal supply is vigorous despite twenty years of war and is exporting; nor need it be a barrier to the uptake of a new crop, as Egyptian clover spread over Pakistan and northern India in a few decades, largely through farmers' own seed production.

The remarks about seeds are often also applicable to legume inoculants, which have the added problem of difficult storage, especially under high ambient temperature conditions. Even when inoculant production facilities are available in-country, there are serious problems in distribution, especially in hot climates, and in training extension staff and farmers in their use.

Hay must be made rapidly and each activity completed on time; purely manual work, therefore, is highly labour-demanding and only small quantities can be made. Ways should be sought of speeding up operations to improve timeliness and increase the area that can be handled at one time with the available labour. Frequently, however, only the most rudimentary tools are used, so even a sharp sickle instead of a saw-edged tool designed for cereals would speed up work and cut more cleanly. A simple fork or rake for turning is a great improvement over turning by hand, yet such tasks are often done without tools, perhaps because women and children often undertake them. There is scope for training and demonstration here, as the technology required should be well within the capabilities of a village smith and carpenter. Animal-drawn equipment is often difficult to obtain, and mowers designed for horses do not suit oxen. In many areas, however, contract mowing by tractor, now common for wheat in some places, may be ousting animal-powered work.

Simple improvements in haymaking techniques could improve quality in areas where they are not yet used. Two such improvements are the use of tripods and similar aids to aeration in humid areas where wood is cheap, and better swath handling and trussing to reduce leaf-fall in arid zones.

CROP RESIDUES

These were always important in many places, and are increasing in importance as the availability of "free" grazing decreases with expanding cultivation. The initial emphasis would be on early and careful harvest and storage. Proper use and supplementation is essential for such coarse feed, and this should be part of any training. Cereal improvement programmes are becoming increasingly aware of the importance of straw and stover in small-scale farm systems, but the impact of this has still to be felt in the field. Residues are easier to dry than hay, and are used in all but the wettest climates. Conservation of rice straw in very wet climates and sites presents particular problems, and treatment with ammonia or urea can be used as a fungicide and preservative, as well as a means of improving palatability and feeding value.

Treatment with urea and ammonia is now a well-understood method of improving the feeding value of straws and stovers. Its applicability should always be studied in any area where they are available; the main factors governing its use are economic and vary widely from place to place.

TECHNOLOGY TRANSFER AND TRAINING

There are many hay crops and ways of making hay and using crop residues; some areas are more advanced than others in growing or curing. Within an area it should be possible to transfer adapted technology with little risk, preferably through farm visits. Transfer between neighbouring areas with similarities can have excellent results, preceded by some simple testing and demonstration, as the case study on Pakistan's Northern Areas shows. Technology transfer between dissimilar areas and farming systems, however, has a long history of failure, especially "demonstration farms" of a different scale from the surrounding small-scale farms.

Figure 63. Technology transfer must be adapted to the local farming system; "model farms" showing technology developed elsewhere rarely work. Hay transport at Ambatondradama, Madagascar, with an ill-adapted cart and labour force who have not been trained to load it.

Farmer training is a high priority; in countries where sown fodder and hay are traditional, improved and appropriate technology and cultivars are available at research institutions and have been for many years, but have not reached the farmers. Often this is mainly because the farmers have not heard of them or do not have access to their seeds. Research which does not reach the field is wasted. Much could be done by firstly making technicians aware of these results through in-service training and, thereafter, to farmers. Such demonstration and training must be through on-farm work with collaborating and participating farmers to ensure that the conditions are those of the target group. Talks and audio-visual aids can be used, but the greatest impact is usually through a spread of on-farm fields and farmer-to-farmer information exchange. As for the technicians so for the farmers: hay and fodder must be put in the context of their farming systems, as a component of livestock feeding, and all aspects should be dealt with: from land preparation, through growing and curing, to storage and use. Crop residue harvest, storage and treatment may be dealt with at the same time, since it is so closely related and will almost certainly be done by farmers already.

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Annex 1
GLOSSARY OF CROPS MENTIONED IN THE TEXT

Botanical name	**Common name(s)**	**Common synonym(s)**
Acacia albida Del.		*Faidherbia albida*
Acroceras macrum Stapf	Nile grass	
Alhagi sp.	camel thorn	
Arachis hypogaea L.	groundnut, peanut	
Astragalus adsurgens	North China milk-vetch	
Astragalus sinicus L.	Chinese milk-vetch, gege	
Astragalus spp.	locoweed	
Atriplex spp.	saltbush	
Avena byzantina C. Koch.	black oat, red oat	
Avena sativa L.	common oat	
Avena strigosa Schreb.	bristle-point oat	
Beta vulgaris L.	beet, mangold	
Brachiaria mutica (Forsk.) Stapf	Pará grass	
Brassica campestris L.	turnip and rape	
Brassica napobrassica (L.) Mill.	swede, rutabaga	
Bromus unioloides Kunth.	rescue grass	*B. catharticus*, *B. marginatus*
Cenchrus ciliaris L.	buffelgrass	
Ceratonia siliqua L.	carob, locust	
Chloris gayana Kunth.	Rhodes grass	
Coronilla varia L.	crown-vetch	
Cyamopsis tetragonaloba (L.) Taub.	guar, cluster bean	*C. psoraloides*
Cynodon aethiopicus Clayton and Harlan	giant African star grass	*C. dactylon*
Cynodon dactylon (L.) Pers.	star grass, Bermuda grass	
Cynodon nlemfuensis Vandersyst	African star grass	*C. polystachyon*, *C. dactylon*
Dactylis glomerata L.	cocksfoot, orchard grass	
Diplachne fusca (L.) Beauv.	kullur grass	*Leptochloa fusca*
Echinochloa frumentacea (Roxb.) Link.	barnyard millet	
Eleusine coracana (L.) Gaertn.	finger millet	
Eragrostis curvula (Schrad.) Nees.	weeping love-grass	

Botanical name	Common name(s)	Common synonym(s)
Eragrostis tef (Zucc.) Trotter	teff	*E. abyssinica*
Festuca arundinacea Schreb.	tall fescue	*F. elatior*
Galega officinalis L.	goat's rue	
Gleditsia triacanthos L.	honey locust	
Glycine max (L.) Merr.	soya, soybean	*G. hispida, G. soja, Soja max*
Hedysarum coronarium L.	sulla	
Hordeum vulgare L.	barley	
Lathyrus sativus L.	chickling vetch, grass pea	
Leucaena leucocephala (Lam.) De Wit		
Lolium multiflorum Lam.	Italian ryegrass	*L. italicum*
Lolium perenne L.	perennial ryegrass	
Lotus corniculatus L.	birdsfoot trefoil	
Lotus uliginosus Schkuhr.	big trefoil	*L. pedunculatus, L. major*
Medicago falcata L.	sickle-pod lucerne	
Medicago media Pers.	variegated lucerne	
Medicago sativa L.	lucerne, alfalfa	
Melilotus alba Desr.	sweet clover	
Melilotus officinalis (L.) Pall.	sweet clover	
Melilotus indica (L.) All.	senji, Indian clover	
Melilotus suaveolens	Daghestan clover	
Morus alba L.	mulberry	
Morus serrata Roxb.	Himalayan mulberry	
Olea europaea L.	olive	
Onobrychis viciifolia Scop.	sainfoin	
Ornithopus compressus L.	yellow serradella	
Ornithopus compressus Brot.	pink serradella	
Opuntia ficus-indica (L.) Miller	prickly pear	
Panicum miliaceum L.	millet, proso	
P coloratum L.	coloured Guinea-grass; kleingrass	
P. coloratum var. *makaraikariensis*	makarikari grass	

Botanical name	**Common name(s)**	**Common synonym(s)**
P. maximum Jacq.	Guineagrass	
P. maxiuum var. *trichoglume*	slender guinea	
Paspalum dilatatum Poir.	dallis grass	
Pennisetum americanum (L.) K. Schum.	bulrush millet	*P. typhoides*
Pennisetum purpureum Schumach.	elephant grass, Napier grass	
Phalaris arundinacea L.	reed canary grass	
Phleum pratense L.	timothy	
Pisum sativum L.	pea	*P. arvense*
Prosopis juliflora DC	algaroba, mesquite	
Puccinellia sp.	salt grass	
Secale cereale L.	rye	
Senecio jacobea	ragwort	
Sesbania sesban (L.) Merr.	dhaincha, jantar	*S. aegyptica*
Setaria italica L.	fox-tail millet	
Setaria sphacelata (Schum) Stapf and Hubbard		Nandi setaria
S. anceps var. *sphacelata*		
Sorghum almum Parodi.	Columbus grass	
S. arundinaceum var. *sudanense*	Sudan grass	
S. bicolor (L.) var. *vulgare*	sorghum	*S. vulgare*
S. halepense (L.) Pers.	Johnson grass	
Trifolium alexandrinum L.	Egyptian clover, berseem	
Trifolium fragiferum L.	strawberry clover	
Trifolium incarnatum L	crimson clover	
Trifolium pratense L.	red clover	
Trifolium repens L.	White clover	
Trifolium resupinatum L.	shaftal, Persian clover	*T suaveolens*
Trigonella foenum-graecum L.	fenugreek	
Triticum aestivum L. Thell.	wheat	
Vicia atropurpurea Desf.	purple vetch	
Vicia dasycarpa	woolly-pod vetch	
Vicia sativa L.	common vetch	
Vigna unguiculata (L.) Walp.	cowpea	
Zea mays L.	maize, corn (USA)	

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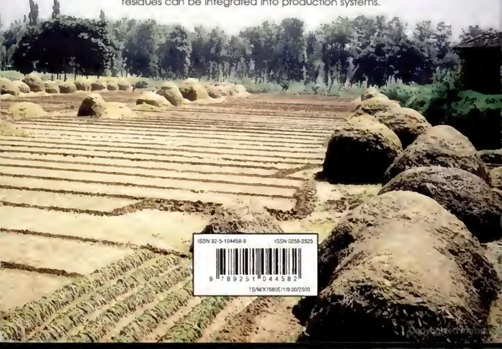
This publication describes the conservation of hay and crop residues for livestock feed. It emphasizes the pastoral and small-farm sector and is aimed at extensionists and trainers of farmers.
It deals with the haymaking process, cultivation of hay crops and management of natural hay fields as well as the harvest and conservation of crop residues as animal feed.
Simple methods adapted to small farms are emphasized throughout. The choice of crop according to farming system and agro-ecological zone is discussed as is the use of conserved fodder. A series of case studies from Asia, Africa and Latin America illustrates how hay and crop residues can be integrated into production systems.



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